BUCKMASTER'S TEXT-BOOK - PHYSIOLOGY -

THE ELEMENTS
OF
ANIMAL PHYSIOLOGY.

BY

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SECOND EDITION.

LONDON:

LONGMANS & CO., SIMPKIN, MARSHALL, & CO.,

JAMES THIN, 55, SOUTH BRIDGE, EDINBURGH.

W. AND J. SULLIVAN, 27, MARLBOROUGH STREET, DUBLIN.

AND ALL BOOKSELLERS.

MDCCCLXIX.

J. & W. Rider, Printers, 14, Bartholomew Close, London, E.C.

PREFACE TO SECOND EDITION.

SOME four years ago I was induced to make arrangements for the publication of a work on Animal Physiology. As I was too much occupied with my official duties I agreed with a science-teacher (Mr. Angell), whom I believed thoroughly competent to prepare the manuscript. I think it right to mention this because I have never wished to take credit for what does not properly belong to me.

In this edition I have taken advantage of many suggestions and hints given by experienced teachers, so as to render the work more suitable as a text-book for Science Classes. I do not think anything is omitted which is necessary for an elementary knowledge of Animal Physiology and the examinations of the Science and Art Department; at the same time a teacher should always supplement the information given in a class book by the reading of other books, and fully explain technical terms which it is impossible

to avoid in science teaching. I have added a short Glossary, which I hope will be found useful, and Classes in Animal Physiology should endeavour to obtain Marshall's Diagrams. The following remarks of the Examiner are well worthy the attention of Teachers :—

"I am quite aware of the practical difficulties in the way of putting even the leading parts of elementary physiology and physiological anatomy before schoolboys and schoolgirls; but they are to be overcome by a little patience and ingenuity.

"The circulation of the blood and the chief properties of living nervous and muscular tissue may be demonstrated with great ease upon one of the commonest of animals, the frog; and a butcher's shop will supply the means for demonstrating all that is essential in the elements of the physiological anatomy of man."

J. C. BUCKMASTER.

ST. JOHN'S HILL, WANDSWORTH, S.W.,
January, 1869.

TABLE OF CONTENTS.

The Elements of Animal Physiology.
Importance of a knowledge of Chemistry in Animal Physiology.
Waste—The Living Body considered as a Machine.
Digestion and Organs of Digestion.
Intestinal Digestion and the small and large Intestines.
Absorption—The Lymphatics and Lacteals.
Food—Hunger and Thirst.
Summary of Food—Hunger and Thirst.
The Blood.
Circulation and the Organs of Circulation.
Respiration and the Organs of Respiration.
Animal Heat.
Nutrition and Repair.
Secretion and Excretion.
The Liver, Gall-Bladder, and the Bile.
Salivary Glands.
Pancreas and Pancreatic Juice.
Ductless Glands.
The Kidneys and their Excretion.
The Structure and Functions of the Skin and its Appendages
Animal Mechanics.
The Articulations or Joints.
The Muscles and Tendons and their Functions.
Organs of the Voice and their Functions.
The Nervous System and its Functions.
The Spinal Cord and its Functions.
The Organs of the Senses and their Functions.
The Tissues or Structural Elements and the Membranes.
Cell Development and Reproduction.
Death.

CUTS ILLUSTRATING THE WORK.

	PAGE
The Amœba	4
Diagram of the course of the food from the mouth to its entering the blood at the jugular vein	28
Human teeth	31
Section of tooth	32
Microscopic section of enamel	33
Development of teeth	35
Vertical section of the throat and mouth	38
Section of the stomach	43
Front view of the organs of the thorax and abdomen	44
Diagram illustrating gastric peristalsis	47
Mucous membrane of the stomach	48
Gastric follicle	49
Capillaries of gastric follicles	51
Diagram illustrating osmosis	60
Alimentary canal	62
Vertical section of coats of small intestines	63
Inner surface of intestines	69
A Villus	70
Capillary plexus or villus	71
Brunner's gland	72
Thoracic duct and lacteals	90
Diagram from Professor Huxley's lectures	93
Human blood corpuscles	118
Diagram showing the circulation of the blood	125
Theoretical section of the human heart	127
Upper surface of the heart	129
Theoretical diagram of the circulation of man and mammalia	131
Theoretical diagram of the arterial system of man	134
Network of capillaries	137
Semilunar valves	138
Diagram showing the action of valves	139
Lungs, heart, and principal bloodvessels of man	141
The thorax with its principal muscles	146
Plan of portion of back of thorax	147

PAGE
Plan of portion of side of thorax ... 148
Trachea and lungs ... 151
Lung-sacs and air-cells ... 153
Diagram illustrating the passage of the air into the lungs ... 155
Plan of structure of secreting membrane ... 159
Stomach, liver, and pancreas ... 161
Structure of human liver ... 162
Hepatic vein and lobules ... 162
Transverse section of three lobules of liver ... 164
Transverse section of two lobules ... 165
Portion of salivary gland injected with mercury ... 169
Portion of spleen ... 172
Plan of urinary organs ... 174
Section of kidney and suprarenal capsule ... 175
Plan of circulation in kidney ... 176
Section of skin ... 180
Dermis and papillæ of foot ... 183
Pacinian corpuscle ... 184
Sudoriparous gland ... 186
The human skeleton ... 190
The human skull ... 195
The vertebral column ... 197
Top of atlas or first cervical vertebra ... 199
Axis or dentate vertebra ... 199
Side of vertebra ... 200
Top of vertebra ... 200
Bones of thorax ... 202
The scapula ... 204
The humerus ... 205
The os femoris ... 207
Bones of the right foot ... 209
Levers in the human body ... 210
Diagram showing vibration of membrane ... 215
Side of larynx ... 216
Front view of larynx ... 216
Thyroid cartilage ... 217
Interior of larynx ... 219
Bird's-eye view of larynx ... 220
Plan of nervous system in man ... 224
Plan of vertical system of the brain, and the columns of the medulla oblongata ... 226
Vertical section of the human brain, with cranial nerves ... 228

PAGE
Anterior surface of the medulla oblongata 233
Plan of transverse section of spinal cord and its membranes 236
Diagram showing course of sensory and motor nerve fibres... 237
Interior of the nose 243
General view of the human ear 244
The eyes and the muscles of the left eyeball 246
Vertical section of the human eye 248
White fibrous tissue 256
Yellow fibrous tissue 256
Areolar tissue 257
Section of cartilage 258
Microscopic structure of bone 259
Longitudinal section of bone 260
Section of dentine 261
Portion of voluntary muscle 262
Sarcolemma 263
Non-striated muscular fibre.. 263
Structure of nerve tubes 264
Plan of section of a nerve fibre 265
Vesicular nerve substance 266
Epithelium cells 269
Structure and development of cells 271

THE ELEMENTS

OF

ANIMAL PHYSIOLOGY.

NATURAL bodies may be divided into two classes—animate, or organized bodies, which possess life; and inanimate, or unorganized bodies, which neither possess life nor have been derived from those which have possessed it.

Animate, or living bodies, are characterized by a peculiarity of structure termed organization; that is, they are made up of organs, and are described as organized beings.

Organs are parts of the body which perform functions or duties. Thus, the brain is the organ of the mind; the eye is the organ of sight; the nose of smell; the stomach of digestion; and the lungs, liver, and kidneys are organs of excretion—that is, they separate poisonous or injurious substances from the blood.

The function of an organ, then, is the office or duty which it performs.

An organized structure consists of a combination of organs, each of which differs in structure from the rest, and performs some function necessary to the well-being of the whole. Thus the human body consists of bones, muscles, nerves, brain; organs of digestion, circulation, respiration, secretion, and excretion. If either of these organs cease to perform its functions properly, disease or death will ensue, accord-

ing to the importance of the organ. If, for example, the lungs cease to perform their functions, the blood will become poisoned with carbonic acid, and death will ensue. If the kidneys, which secrete the urine, cease to perform their function, the blood will become charged with urea, which will poison the brain, and produce insensibility, and ultimately death.

A tissue is the simplest form of organized structure. An animal or a plant may be separated into complete structures termed organs; these may be resolved into others of a simpler character, which cannot be further disintegrated without resolving them into the proximate principles of which they are composed, and entirely destroying them as structures.

The tissues preserve their distinctive characters in whatever parts of the body they are found, just as the stone, brick, iron, and mortar of a building retain their general character and properties into whatever portion of the building they enter. The principal tissues are—white and yellow fibrous tissue, areolar or connective tissue, cartilaginous tissue or gristle, fibro-cartilage, osseous tissue or bone, adipose tissue or fat, muscular tissue, and nervous tissue.

Proximate Principles, or Organic Compounds. —When the tissues are disintegrated they lose all trace of structure, and are resolved into certain chemical compounds, which are of a very peculiar and complex character, and, with one or two exceptions, cannot be produced by artificial means.

The most important of these principles are—albumen, casein, fibrin, syntonin, globulin, and fat. All these bodies, excepting fat, abound in nitrogen, and are therefore termed nitrogenous substances.

Ultimate Principles, or Chemical Elements.—When the organic compounds of which the tissues

are composed are subject to complete decomposition, they lose their organic character, and are resolved into their ultimate elements, which are common to the inorganic or mineral world.

About sixty simple bodies, or ultimate elements, are known to the chemist. Of these about eighteen enter into the composition of organic beings; these are—oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine, iodine, bromine, fluorine, silicon, potassium, sodium, calcium, magnesium, aluminium, manganese, and iron. Oxygen and hydrogen enter into the composition of all organized beings; nitrogen and carbon are also frequent constituents of these bodies. These four elements are termed organogens, or essential elements. The remaining elements, of which only minute quantities, and in some instances traces only enter, are termed incidental elements. Iodine and bromine are only found in marine animals, while traces of fluorine are found in the teeth and bones only.

Organized Bodies are divided into plants and animals. These bodies may either be active, dormant, or dead. The seed of a plant during the process of germination is in a state of activity or growth. It may exist for centuries in a dormant state; or it may exist in a state of death, in which state, though presenting all the ordinary forms and properties of organization, it is perfectly incapable, from the want of the vital principle, of manifesting the phenomena of life.

Life.—The vital principle is the force or influence by which organized beings are enabled to perform their functions, or, in other words, to live. The ultimate principles, or chemical elements, under the influence of vital forces, unite to form proximate principles; these, again, are built up into tissues; the

tissues are elaborated into organs; and the organs together form the perfect animal.

Low Organization.—When an organized being has but few organs performing distinct functions, or is made up of a repetition of similar organs performing similar functions, it is said to be of low organization. If such animals be injured, or portions of them be cut off and removed, the life of the animal is not endangered, but the part removed will, in many cases, develop into a complete animal. In others the lost part will be restored, as in the case of the star-fish, which may lose two or even three of its limbs, each of which will be restored to it, the life of the animal being in no wise endangered. The bodies of worms, which are made up of a considerable repetition of parts, may also be mutilated without affecting the life of the animal. In general, the fewer number of organs, the lower are the functions, and the less their importance to the general life of the animal. The amœba is a type of "low organization."

THE AMŒBA,

A jelly-like mass, found in fresh and stagnant water; has no mouth, stomach, or other organ; but can extend a portion of itself in any direction, and seize, surround, and digest its food.

High Organization.—When an animal, as in the case of man, is endowed with a great number of different organs performing different functions, it is said to be of high organization. In the bodies of the higher animals there is an absence of the repetitions found in those of the lower animals. In animals of high organization the relation of the various organs to each other is of the most intimate nature, and any injury to one of the organs not only affects the function of that organ, but disturbs the action of the whole, and may even produce death. Any serious injury to the brain, the heart, or the lungs will produce death, though the other organs remain uninjured. The higher the organization of the animal, the less is its power to reproduce a lost part. Also the higher the organization of an injured tissue in any animal, the less its capability of restoring the same. It is said that if a piece of nerve be cut out it will not again be fully restored, but will be supplied by a lower form of tissue.

The Physical Forces in Living Beings.—The action of the air on the blood in the process of breathing, the conversion of food into blood, the production of animal heat, the destruction of the tissues, and the daily waste which necessitates a fresh daily supply of food, are chiefly chemical processes. Circulation is an almost purely mechanical process; the passage of the fluids through the walls of their containing vessels, veins, and arteries, under the influence of *exosmosis* and *endosmosis*, are all to a greater or less extent physical processes, which may be imitated by art. Electricity also plays a part in the operations of the animal economy.

The arrangement and operation of the bones, muscles, and joints are in strict harmony with ordinary mechanical laws. The eye and ear are constructed in

relation to the laws of optics and acoustics. A knowledge of chemistry, mechanics, and natural philosophy will help to a clear understanding of the structure and functions of the human body.

Physiological Labour has been divided into the following branches :—Anatomy, physiology, pathology, and histology.

Anatomy (Gr., *ana*, through, and *temno*, I cut) is the science which treats of the form and structure of the various parts of the body. It is studied by the dissection of the bodies of dead animals.

Physiology (Gr., *phusis*, nature, and *logos*, a discourse) is the science which treats of the functions of the various parts of the body, and the laws of health. It is studied by observations on the living body in a state of health, aided by a knowledge of other sciences.

Pathology (Gr., *pathos*, feeling, and *logos*, a discourse) is the science which treats of the functions of the various parts of the body in a state of disease. It has been described as the science of abnormal function. It is studied by observing the living body under all the various phases of disease.

Histology (Gr., *histos*, a web, and *logos*, a discourse) is the science which treats of the microscopical structure and the functions of the tissues.

Difference between Plants and Animals.—In their higher forms animals are easily distinguished from plants; but in their lowest they approximate so nearly to each other in their general characters that they are distinguished from one another with great difficulty.

Animals differ from plants in their chemical composition, shape, structure, nutrition, mode of growth, and, in their higher forms, by the possession of the powers of voluntary motion and sensation.

Animal substances are more complex in their composition, and generally contain more nitrogen, which is absent in large classes of vegetable substances.

Animals are more compact in their structure than plants, and usually contain one or more internal cavities, or stomachs, into which food is introduced by means of an external opening, where it undergoes a change so as to enable it to be absorbed into the body for the purposes of nutrition. Plants, on the contrary, obtain their food by absorption through their external surfaces, and therefore do not possess or require stomachs.

Animals are nourished by interstitial deposit taking place through their entire mass, internal and external, thus necessitating a more or less complex circulatory apparatus; while plants are principally nourished by deposit on their external surfaces, their interior undergoing comparatively little change: they therefore do not require a proper circulatory apparatus.

The reproductive organs of plants fall each year; those of animals are permanent during life.

Animals are endowed with the power of sensation and of voluntary motion, which, in the higher animals, form their leading features, and necessitate a muscular and a nervous system. Plants possess no such powers.

Animals, viewed in relation to the air, are reducing agents. They reduce the air, or remove its oxygen, in the process of breathing, by combining it with the carbon of their own bodies; and expel it in the form of carbonic acid gas, by which the purity of the atmosphere is vitiated. Plants, on the contrary, are chiefly oxidizing agents; they remove the poisonous product of animal respiration, converting the carbon into their own substance, and restoring the oxygen to the atmosphere.

Organic or Vegetative Functions.—Many of the functions performed by living bodies are common to both plants and animals; they are termed the functions of organic life. They are digestion, absorption, circulation, respiration, nutrition, secretion, excretion, and reproduction.

Digestion (L., *dis*, asunder, and *gestus*, carried) is the process by which the nutritious parts of the food are converted into blood.

Absorption is the process by which liquids are absorbed into the system by means of veins, and a system of vessels termed absorbents.

Circulation (L., *circulus*, a circle) is the process by which the blood is carried out from the heart, and returned again to the heart, from the various parts of the body.

Respiration (L., *re*, again, and *spiro*, I breathe) is the process by which the blood is purified, and carbonic acid excreted by contact with the oxygen of the atmosphere. The principal organs of respiration are the lungs.

Nutrition (L., *nutrio*, I nourish) is the process by which the various tissues of the body are built up, and repaired out of the constituents of the blood.

Secretion (L., *secerno*, I separate) is the process by which fluids and other substances necessary to the proper performance of the functions of the body, are separated or elaborated from the blood by means of glands or other organs. The saliva, or spittle, is elaborated from the blood by the salivary glands, and is necessary to perfect digestion.

Excretion (L., *ex*, out, and *cerno*, I sift) is the process by which the waste products of the tissues, and other injurious substances, are separated from the blood, and thrown out of the body by means of glands

or other organs. The urine is a poisonous substance excreted from the blood by the kidneys. In the disease termed *ischuria* the kidneys are unable to perform this function, and the blood becomes poisoned with *urea*, which soon produces insensibility and death.

Reproduction is the process by which life is perpetuated and the species propagated.

Animal Functions.—In addition to these functions as common to plants and animals, animals are characterized by the performance of certain functions which are not necessary to their mere existence as living beings, but by which they are brought into more intimate relation with each other, and with the surrounding world. These functions are termed the functions of relation, or animal functions; they are spontaneous motion, sensation, thought, and speech. The two latter functions are characteristic of the higher animals only.

Spontaneous Motion.—The power of spontaneous motion is common to all animals. All excepting the lowest classes of animals possess the power of locomotion; by which they are enabled to seek their food. Man is enabled, by the exercise of this power, to bring himself into relation with any department of nature, and with the rest of the human family, for the purpose of cultivating his mind and availing himself of the forces which nature has placed at his disposal. Without this power the brain would be comparatively useless.

Sensation (L., *sentio*, to perceive) is the process by which we become conscious of internal or external impressions through the agency of the brain and nerves.

Thought.—The power of thought, including under

this term the various powers of the mind, as consciousness, volition, the affections, and the intellect, is dependent on the healthy action of the brain.

IMPORTANCE OF A KNOWLEDGE OF CHEMISTRY IN PHYSIOLOGY.

As probably many of our readers will not previously have been through a course of chemical study, it becomes necessary to explain with some accuracy what ideas are intended to be conveyed by the terms acid and alkali, so frequently used in describing the digestive juices. Without accurate ideas on these subjects no really scientific knowledge of the nature of digestion, and of many other physiological processes, is attainable. Professor Huxley, in a report on the Government Science Examinations in Physiology, strongly complains of that pretentiousness to physiological knowledge on the part of some candidates, which permits such gross perversions as the describing of the gastric juice as an alkaline fluid, and the bile as an acid fluid. It is quite clear that in such cases, which are unfortunately very common, the student has adopted certain terms without realizing their true value. In the course of this little book we repeatedly go a little out of our way to give so much of chemical knowledge as is necessary to a sound and real explanation of the subject immediately treated of; but these explanations are in no instance intended to supply the place of a systematic study of chemistry, and the reader is again advised to join one of the numerous Science Classes established all through the country, by the aid of the Department of Science and Art, with the view of promoting the

national study of science. There is but one mode of studying the physical sciences. No mere verbal description, whether by book or by the living voice, can supply the place of actual observation on the part of the student.

It is absolutely necessary, whether for the purpose of mental training or practical ability, that the student should know, by his own observation, the leading and distinctive physical and chemical properties of all ordinary bodies, together with the phenomena which result from these properties.

Acids are substances which are distinguished by certain well-marked and characteristic qualities. When soluble they have a sour taste, and redden vegetable blues. They have a powerful affinity or chemical attraction for a peculiar class of compounds termed bases, the majority of which consist of compounds of oxygen and a metal. This latter combining power is their most general and distinctive characteristic. When they enter into combination with these bases they neutralize them —that is, cause their peculiar properties to disappear for the time; their own peculiar properties also disappearing simultaneously. Some acids are insoluble in water, and therefore neither possess a sour taste nor are capable of reddening the vegetable blues. Strong vitriol or sulphuric acid dropped on to a silk dress or a black coat will immediately produce red spots. These spots will soon fall into holes unless the acid be immediately neutralized. Solution of ammonia (or hartshorn) applied immediately will restore the colour, and delay the formation of the holes. The ammonia is a base, and it neutralizes the acid.

Experiment I.—Procure some strong vinegar. Observe it has an intensely acid or sour taste. Drop a little of it into a solution of blue litmus, and observe

that it is immediately changed from a deep blue to a bright red colour. Procure a little of the common carbonate of soda, such as is used in "washing;" dissolve a little in water, and add it slowly to the reddened litmus solution. Observe that its bright red tint immediately disappears, and that its original blue colour is immediately restored. The soda (an alkaline base) of the carbonate of soda added has neutralized the acid properties of the vinegar, which consists of impure acetic acid. The colour of common red ink is due to the acid it contains. This acid quickly corrodes steel pens; from which circumstance it is always advisable to use quill pens in writing with red ink.

EXPERIMENT II.—Place a common egg in a tumbler, and fill the remaining space in the tumbler with strong vinegar; in the course of a few days the egg-shell will have entirely disappeared. The vinegar (acetic acid) will have combined with the earthy matter of the shell, which is chiefly composed of lime, a powerful base, and the compound so formed will have completely dissolved, leaving the egg shell-less, and completely exposing its lining membrane. A more powerful acid will effect this result with much greater rapidity.

EXPERIMENT III.—Drop a few drops of sulphuric or hydrochloric acid into a glass containing white of egg (albumen). The acid will immediately coagulate or solidify the albumen of the egg, forming a white, opaque, soft, solid substance, similar to that produced by boiling an egg.

Dr. Beaumont states that liquid albumen taken into the stomach is in like manner coagulated by the action of the gastric juice, but this is strongly denied by other physiologists.

The presence of a sufficient quantity of free (uncom-

bined) alkali will prevent any of the results obtained in these experiments.

Acids at ordinary temperatures produce no change on fatty substances.

The Alkalies are exceedingiy soluble bodies, possessing properties entirely unlike those of the acids. The chief alkalies are potash, soda, and ammonia. They have a strong, pungent, acrid, but when dilute, soapy taste: do not redden blue litmus, but restore the original blue of reddened litmus. They also turn purple cabbage water green, and change the bright yellow of turmeric (a yellow dye) to a decided brown. The alkalies neutralize acids, and enter in minute quantities into the composition of most organic compounds. Their most important property in a physiological point of view is their power of forming soluble compounds with fatty substances. When oils and fats are heated with potash or soda, they form certain chemical compounds termed soaps.

A familiar idea of the taste, general appearance, and properties of an alkali may be derived from common domestic washing soda, which is an impure compound of the alkali (soda) and carbonic acid, the acid being too feeble to entirely neutralize the powerful basic properties of the soda.

Lime, magnesia, and some other similar bodies, in many respects chemically resemble potash and soda, but possess a very much lower degree of alkalinity; they have therefore been termed alkaline earths.

The blood is slightly alkaline from the presence of soda. The bile, the pancreatic and intestinal juices are also more or less alkaline; hence their power of acting upon the fatty substances of the food during intestinal digestion.

EXPERIMENT.—Pour some oil into a bottle, and

shake it up until its sides are well greased; pour off the remainder of the oil, and drain the bottle. Then introduce some pure water; well shake the bottle, and pour off the water. You will observe the interior of the bottle is still dirty, and that however frequently the operation be repeated, the bottle will remain greasy. The water cannot combine with oily matter, which in fact repels it, and therefore cannot cleanse the bottle. Again introduce water into the bottle, to which add a small quantity of an alkali (soda or ammonia). Again well shake the contents, which quickly combine, becoming white, opaque, and milky, and forming an emulsion very much resembling chyle in appearance. Pour off the contents, and again well wash. The bottle will now be found quite clean, and free from grease. The oil and the alkali have combined and produced a soluble compound, which is readily removed by washing.

The same theory explains the use of soap in washing the hands or the clothes. The person and the clothes become covered with a more or less greasy exudation: this by its repellent power prevents the thorough contact of the water, which is thereby unable to exercise its cleansing power. Upon the application of the soap, the alkali which it contains combines with the grease on the hands or the clothes, and forms a soluble compound which is immediately dissolved; the water is thus brought into perfect contact with the surfaces to be cleansed, and enabled to exercise its detergent or cleansing power.

Chemistry of the Organogens.—Organic bodies are chiefly composed of oxygen and hydrogen, with which are generally combined carbon and nitrogen. These bodies are termed organogens. As life and all the animal and organic processes, more especially those

of nutrition and respiration, are dependent on the chemical changes that are perpetually taking place among these constituents of the animal frame, a knowledge of their properties is necessary to a clear understanding of these processes, and the student will do well to make himself acquainted with the chemistry of the following elements:—Oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, and chlorine.

Azotized Proximate Principles.—The following azotized organic principles require a brief notice: —Protein, albumen, fibrin, syntonin, casein, globulin, hæmatosin, gelatin, and chondrin.

Protein (Gr., *proteuo*, I hold the first place) is the name given to a substance discovered by Mulder, which he supposed to be the essential constituent of three important nitrogenous principles—albumen, fibrin, and casein. He supposed these bodies to be compounds of protein with different proportions of sulphur and phosphorus. This theory is, however, now generally discarded, though the term is still much used.

Albumen (L., *albus*, white) is the characteristic ingredient of white of egg, and of the serum of blood; the former is sometimes designated *ovalbumen*, the latter *seralbumen*. When perfectly pure, and free from salts and alkali, it is probably insoluble. In its ordinary state, as in white of egg, it coagulates when heated, forming a white, opaque, soft, solid, insoluble substance. Acids, and many salts, especially those of copper and mercury, coagulate it. Albumen is one of the best antidotes in cases of poisoning with salts of mercury, and forms highly nutritious plastic food.

Fibrin is a nitrogenous compound which very closely resembles albumen in its chemical properties and composition. It differs from albumen principally in its power of spontaneous coagulation. Fibrin derives

its name from its property of spontaneously separating from newly drawn blood, in the form of a network of fibres, in which it entangles the red corpuscles of the blood, the whole forming the clot, or coagulum, of the blood.

Syntonin (Gr., *suntonos*, stretched) is the term applied to coagulated or solid fibrin. It is the principal constituent of muscular fibre.

Globulin is the albuminous constituent of the red corpuscles of the blood; it closely resembles ordinary albumen. It occurs mixed with albumen in the crystalline lens of the eye, and is therefore also termed crystallin.

Casein (L., *caseus*, cheese) is the characteristic and most valuable constituent of milk. It is held in solution by the slight excess of free alkali (soda), which fresh milk always contains. When acid is added to milk, or when it turns sour by the formation of lactic acid, the free alkali is neutralized, and the casein separates in the form of large white flakes, termed the curd. Casein, curd, or cheese, when digestible, is one of the most nutritious substances.

Hæmatin, or **Hæmatosin,** is the true colouring principle of the blood. It is a soluble, coagulable, albuminous substance, which contains more iron than any other constituent of the body. According to Mulder it contains 6·6 per cent. of metallic iron. It is said that a French *savant* constructed a mourning ring from the iron obtained from the ashes of a departed friend.

Gelatin, though sometimes described as one of the proximate principles of the animal body, does not exist in the tissues, but is developed by the prolonged action of boiling water upon certain animal textures. Isinglass is nearly pure gelatin. Glue and size are

inferior qualities of gelatin. Fibro-cartilage, white fibrous tissue, the skin and bones, yield gelatin on continued boiling, especially under high pressure. Gelatin is very soluble in hot water. A hot aqueous solution containing 1 per cent. of gelatin will gelatinize, or solidify into the form of a jelly, on cooling. It is precipitated by tannin and several metallic salts.

Chondrin, in general, resembles gelatin, but differs slightly in its chemical composition. The vegetable acids, alum, and the acetates of lead coagulate solutions of chondrin, but do not act upon gelatin. Chondrin is obtained by the action of hot water on the cartilage of the ribs, joints, trachea, nose, and ears.

The non-azotized proximate organic elements are chiefly starch, sugar, gum, lignin, and the fats. They all consist of carbon, oxygen, and hydrogen.

Starch is entirely of vegetable origin. There is no satisfactory evidence that it enters into the composition of animal bodies. It is insoluble in cold water. In the animal body it is first converted into sugar, then dissolved, and absorbed into the blood, and either burnt as respiratory or fuel food, or converted into fat.

Sugars are also essentially a vegetable product. Their general properties are well known. They have a sweet taste, are soluble in water, and more or less crystallizable. They yield carbonic acid and water on fermentation. They constitute respiratory or fuel food, by which the animal heat is sustained, and are convertible into fats. Much of the sugar taken into the body is converted into lactic acid.

Gum is a vegetable product resembling starch and sugar in its general chemical characters.

Fats are compounds of carbon, hydrogen, and a much smaller proportional quantity of oxygen than is contained in sugar or starch; they are, therefore,

greatly superior as heat-giving foods. They are exceedingly combustible. Fats are usually complex substances, containing certain organic principles—margarine, stearine, and oleine.

WASTE—THE LIVING BODY CONSIDERED AS A MACHINE.

All substances when in action, or in contact with moving bodies, lose a portion of their material, and undergo a process of wear or waste.

The mountain tops are gradually lowered; the hardest rock is slowly reduced; our ships, our houses, our machinery, our tools, our clothes, and all implements of domestic use, gradually yield to the destructive agency of this process of wear or waste. A carpenter's plane, and even iron tools are frequently worn into holes by the continued friction of the thumb and fingers. Soft solids, especially those containing liquids, waste more readily than hard ones.

The living body is chiefly made up of soft solids and liquids; it is always in a state of greater or less mechanical activity, and is the seat of continuous and varied chemical action. When powerful mechanical, chemical, and vital activities are combined, this process of waste is greatly increased, and it is supposed that the entire substance of the body is changed in the course of two or three years; and it has been further calculated that a quantity of material equal to the entire weight of the body is carried away every forty days, so that the greater part of our body is renewed in that time.

Starvation proves Waste.—If food be entirely withheld from an adult he gradually loses weight, becoming thinner, lighter, and feebler, until he has lost

about 40 per cent., or two-fifths of his entire weight, when death usually takes place. Death generally occurs in from ten to twenty days, and is very rarely delayed beyond fourteen days. In one or two cases, however, it has not occurred till the twenty-third day after deprivation from food. If an average adult human being be insufficiently fed, he will lose bulk and weight, but in this instance much more slowly than when the deprivation from food is entire. When the bodily loss has amounted to about 40 per cent., which is about the limit consistent with life, death takes place, and the body becomes subject to the ordinary processes of decay.

Rate of Waste.—Various attempts have been made to ascertain the rate of waste in the human body by calculations founded on the amount of the daily *egesta*, or substances thrown out of the body. The daily egesta consist chiefly of carbonic acid gas, about 2 lbs.; water, about 6 lbs.; urea, about 480 grains; salts, 485 grs.; in addition to the fæces, which consist chiefly of the undigested residue of the food.

These egesta are partly derived from the disintegration and oxidation or combustion of the waste tissues, and partly from the oxidation of the food. It has been calculated that about 1½ lb. of the carbonic acid gas, about ⅗ lb. of the water, and about 240 grs. of the urea are derived from the disintegration and combustion of the tissues of the body itself, more especially of the muscular and fatty tissues, the rest being derived from the food, including drink, daily ingested.

The following table, from Brinton, indicates more elaborately the estimated amount of daily bodily waste according to the researches of Valentine and others. The typical man, on whom the calculations are supposed to be based, represents a healthy male, 35 years old,

5 ft. 6 in. in height, and 10 stones in weight. It must, however, be understood that the quantities given are simply approximative, and must vary with constitution, temperature, mental and bodily activity, state of health, and the general condition of the atmosphere :—

TABLE OF DAILY BODILY HUMAN WASTE.

			grs.
Carbonic acid			14,000
Water (8,400 of which are formed by combustion)			42,000
Urea (including carbonate of ammonia, 20 grs, ?)			480
Other organic constituents of the urine: namely, uric acid (8), kreatinin (7), kreatine ($4\frac{1}{2}$), lactic and hippuric acids (indeterminate), together about			20
Salts	by the skin	80	830
	,, fæces	50	
	,, urine	700	
Total			57,330

The carbonic acid and water of the 57,330 grs. of daily matter egested are partially made up of the 14,570 grs. of oxygen daily absorbed by the lungs and skin in the process of respiration. If we deduct from the 57,330 grs. of egesta the 14,570 grs. of absorbed oxygen, the remainder, 42,760 grs. (about 6 lbs.), will show the quantity of food daily required to support the system.

Annual Change of Bodily Substance.—During the course of one year the body consumes about twenty times its own weight of food and oxygen. It receives about 800 lbs. of solid food, about 1,500 lbs. of liquids, and about 800 lbs. of oxygen, which is principally absorbed through the lungs in the process of breathing. The total weight of substances consumed by the body during one year, therefore, amounts to upwards of 3,000 lbs., or about a ton and a half.

The living organism wastes because of the mechanical, chemical, and vital actions to which it is subject.

The mechanical actions are produced through the agency of the voluntary and involuntary muscles, the bones and the ligaments. Every time we move our arm, or wink our eye, a portion of the muscle is destroyed, and requires to be repaired or restored by the process of nutrition. All mental action is performed through the agency of the brain and nervous system, and every time we think, or see an object, or hear a sound, a portion of the brain and nerve of sight or of hearing is destroyed, and ceases to exist as brain or nerve. No animal can continue to exist if its body falls below a certain temperature. A process of slow combustion, or burning, is continually progressing in its substance, by which the animal heat is sustained and the bodily weight is diminished.

The bones, joints, ligaments, and skin are all subject to wear because of the mechanical attrition which they undergo, and therefore require repair. The liquids of the body also suffer loss by evaporation and respiration.

Continual loss is also sustained in the various processes of solution, circulation, and the chemical changes incurred in the processes of digestion and secretion.

Waste is proportioned to Exertion.—Increase of bodily or mental exertion produces increased waste. The bricklayer's labourer or the navvy renews his muscular, osseous, and fatty tissues much more rapidly than the student, and, as a consequence, enjoys a better appetite, possesses a more vigorous digestion, and consumes a much greater quantity of food. During his pedestrian summer tour the quantities of carbonic

acid, water, urea, and salts eliminated from the body of the student, professional man, or clerk, are greatly increased, sometimes even doubled; the quantity of food taken being correspondingly increased. In this way are developed that increase of appetite and vigour, and that consciousness of high health, which go far to counteract the debilitating tendency of all sedentary employments. Again, the brain and nervous system of the student, being much more active than those of the navvy, suffer a much more rapid process of disintegration and repair, and are more frequently and entirely renewed than those of the navvy. In cases of excessive mental labour or study, also in certain cases of mania and insanity, it has been observed that the quantity of salts, especially the phosphates, eliminated in the urine, is greatly increased. The phosphorus in the phosphates is, in this case, derived from the destruction of the brain and nervous tissues; the great increase of the phosphates proving the greatly increased rate of disintegration of brain and nerve consequent on the excessive brain labour.

The Living Body considered as a Machine.—The living body has been compared to a machine performing a certain amount of work, the work being greater the greater the amount of coal or other fuel consumed. In the economy of the living body the expenditure of force is directly proportioned to the oxidation, combustion, or metamorphosis of the food and tissues. This principle is very adequately expressed in the alliterative, "Food is force."

In the working of the steam engine the real agent is the heat. The boiler, cylinder, piston, crank, and wheels may all be complete,—nay, there may be coals and water,—but the machine is motionless; there is no dynamic or moving force. The amount of work done

is directly proportioned to the heat developed and applied; but the heat developed depends on the metamorphosis the coal undergoes in the process of combustion, or, in other words, on the quantity of coal burnt. It is easy to calculate the mechanical power of the steam engine by the quantity of the heat evolved and applied; and it is very easy to calculate the quantity and intensity of the heat evolved by determining the quantity of fuel of a given chemical composition consumed in a given time. Dr. Joule, of Manchester, has determined, after many years of able and laborious experiment, that the quantity of heat which will raise the temperature of one pound of water one degree, measured on the centigrade thermometer, will, if applied mechanically, raise 1,392 lbs. avoirdupois one foot high.

This quantity of heat has therefore been taken as the mechanical unit of heat, and by means of it we are enabled to determine the mechanical equivalent, or moving power of any degree of heat. It has been determined by experiment that during combustion 1 lb. of carbon evolves as much heat as would raise 8,000 lbs. of water one degree in temperature. $8,000 \times 1,392 = 11,136,000$ lbs., or the number of pounds avoirdupois that may be raised through 1 foot of space by the mechanical force evolved in the combustion of 1 lb. of carbon. Again, it has been determined that the heat evolved during the combustion of 1 lb. of hydrogen—that is, by its chemical union with the necessary quantity of oxygen, transmuted into mechanical force, would raise the astounding weight of 47,328,000 lbs. one foot high. But the union of the oxygen and the carbon, and the oxygen and the hydrogen, in the human body is attended by the evolution of the same quantity of heat as in the case of its ordinary combus-

tion outside the body; therefore it is easy to calculate approximatively the mechanical equivalent to the forces set free in the body in the performance of the mechanical, chemical, and vital processes, if we can only determine the respective quantities of carbon and hydrogen consumed or oxidized in the system.

According to Liebig an ordinary man consumes, or converts into carbonic acid, about $13\frac{9}{10}$ oz. of carbon per day. This is probably a little in excess of the true amount. Adopting this estimate, the amount of force generated daily in the human body by the combustion of the carbon alone would, if used mechanically, raise 9,674,400 lbs. avoirdupois one foot high.

Vital Decomposition.—The body, as has been shown, is the seat of constant change. Its particles are continually undergoing a series of changes, of decomposition and degradation,—are incessantly dying and being removed from the system. But the dead particles are as incessantly being replaced by newly formed living ones, so that the body still retains its general life, form, and properties.

General Functional View of Man.—Man is endowed by God with the power of performing numerous more or less complex functions. His highest, noblest, and most distinctive function is thought, including under this term, knowledge, reflection, the religious and moral feelings and emotions, the sentiments and affections. The mind would be unable to act unless brought into relation with the external world through the function of sensation, including sight, smell, hearing, taste, and touch. Unable to perform these functions, wanting in the powers of sensation, his position in this world would be a blank; all would be darkness and chaos. Wanting these windows of the soul, all would be cold, vacant, and cheerless.

Sightless, deaf and dumb, unconscious of all external existence, no light, no colour, no sound, no beauty, no friendship to act on the imprisoned soul, the mind would be a mere blank. But given a mind with all its glorious powers, and the faculties of sensation, without which the mind would be useless, it is still necessary that man should possess the power of bringing himself into contact with new scenes, new agencies, new friends, by which the mind is filled with an ever-flowing current of new thoughts, ideas, and aspirations, and by which he is enabled to collect the material substances essential to the support of his existence,—therefore are added to his endowments the powers of motion and locomotion. But the functions of thought, sensation, and locomotion imply material organs and actions, with their inseparable accompaniments of waste and disintegration. These necessitate other ministering functions, including digestion, circulation, respiration, and nutrition, by which the material organs of the higher functions are kept in a state of continued renovation and repair. And still other functions are superadded, including those of secretion and excretion, by which the effete and worn-out materials of the system are carried away, and health and purity maintained.

General Structural View of Man.—If you were to imagine a human body to be gradually dissected or taken to pieces, beginning from the exterior, the various structures would reveal themselves in the following order:—On the outside, the skin; under it a general layer of fat, more or less perfect. Upon removing the skin and fat a large number of bundles of red flesh (the muscles), which pull the bones and move the body, would be seen. Under these lie the bones, to which the muscles are attached by whitish cords (the tendons). We should then come to the great

cavity of the trunk, including those of the chest and abdomen. The upper part of this cavity is enclosed by the ribs, its lower being enclosed by soft walls only. This cavity contains the blood-making organs (the organs of digestion), the blood-purifying organs (the lungs), a force-pump (the heart), a system of blood-pipes for distributing the building and repairing material through the body, and a system of sewerage (the liver, kidneys, and intestines), by which the purity of the commonwealth is maintained.

Behind the great cavity, and enclosed within the bones of the spine and skull, is another, a smaller cavity, in which is situated the great telegraphic apparatus (brain and nerves), which sends out silver strings (nerves) to all parts of the body, and guides and directs the machinery of the whole. To the trunk, or main system, are appended four extremities or limbs, two upper and two lower, which are also intimately connected with the central telegraph apparatus, by means of its silver strings, and with the blood-making and blood-distributing system, by means of branches of the blood-pipes previously referred to.

The following table will aid the reader in forming a clearer view of the animal organs and functions :—

TABLE OF ORGANS AND FUNCTIONS OF MAN.

	Functions.	*Organs.*
Functions of Relation . . .	Thought and Sensation . .	Brain. Nerves.
	Voice . . .	Larynx. Vocal cords.
	Motion and Locomotion . .	Nerves. Muscles. Tendons. Bones. Ligaments.

	Functions.	*Organs.*
Vegetative or Organic Functions	Renovation and Repair	Stomach and organs of digestion. Heart, or organs of circulation. Capillaries, or organs of nutrition. Lungs, or organs of respiration.
	Removing the Waste	Absorbents, or lymphatics. Organs of respiration. Organs of secretion. Organs of excretion.
	Organs of Reproduction.	

Development.—All animals originate in a germ, or cell. The germ, cell, or egg from which the higher animals, including man, originate, differs but little in form and structure from those out of which the lower animals are developed. Life would, therefore, appear not so much to depend upon organization as to determine it, since all the higher forms of organization are developed from the lower. There is, first, the simple cell; this, by a process of development, or differentiation, divides and subdivides into other cells; these unite to form tubes, vessels, fibres, which again unite and constitute organs. The extent to which this process of differentiation, or development, can proceed, determines the high or low organization of the animal, which appears to depend on the vital principle inherent in the original germ-cell.

DIGESTION AND ORGANS OF DIGESTION.

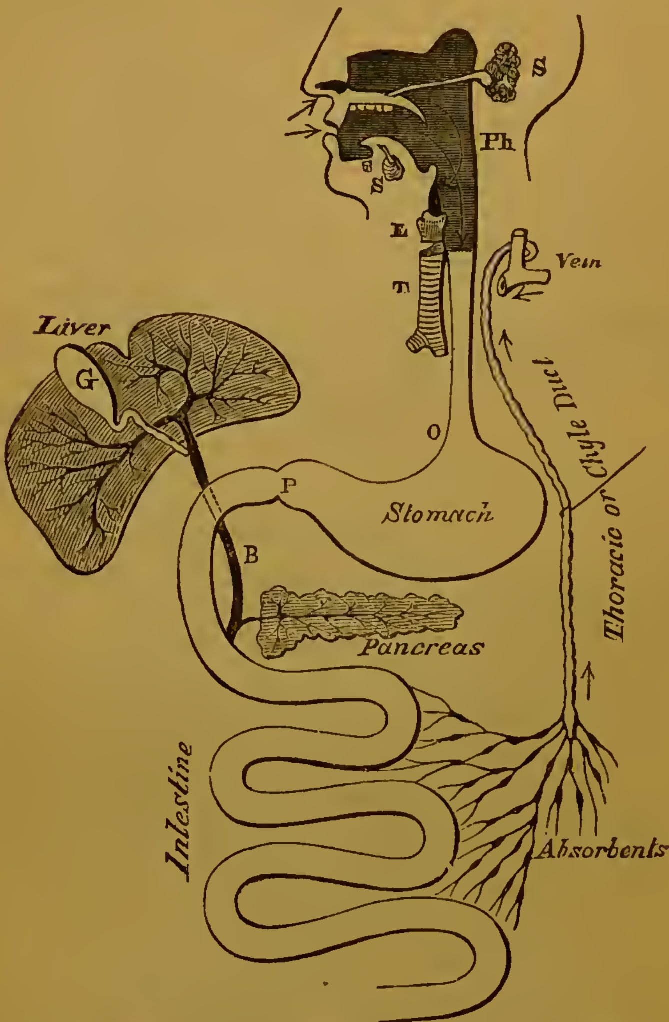


Fig. 1.—Diagram of the course of the food, from the mouth to its entering the blood at the jugular vein. S, S, s, the three Salivary Glands. Ph, the Pharynx, the cavity behind the nose, mouth, and larynx. The two arrows show the course of the air from the nose to the larynx, and of the food from the mouth to the œsophagus. L, Larynx. T, Trachea. O, Œsophagus or gullet, terminating in the stomach. P, Pyloric orifice and valve between stomach and duodenum. G, Gall bladder and its duct. B, Bile duct, uniting with duct of pancreas.

General View of Digestion.—In the process of digestion, or blood-making, the food is first broken or crushed, as in a mill, the teeth acting as the cutters or grinders. It is then passed into the stomach, where the nutritive material is gradually dissolved out by the agency of certain fluids, aided by warmth and agitation. The stomach may, in this respect, be regarded as a sort of "chemical digester," or solution bottle. The nutritive solution is absorbed into the blood almost as rapidly as it is formed. The remaining portions, consisting principally of the insoluble and useless parts of the food, are then slowly squeezed and pushed along the intestinal tube, until they are driven out of the body as effete and injurious material. They are, however, at first mixed with more or less undissolved nutriment, which has escaped solution in the earlier stages of the process. This is gradually dissolved by the aid of other juices which it meets on its journey through the system, and is also absorbed and mixed with the blood.

The liver, pancreas, and other organs aid digestion by supplying the necessary solvent juices.

Digestion is the process by which the nutritious parts of the food are converted into blood, and the innutritious, or non-blood-forming parts, are expelled from the body. It comprises eight sub-processes—prehension, mastication, insalivation, deglutition, chymification, chylification, absorption, and defæcation.

Prehension, or the taking of food into the mouth, is chiefly performed by the hand, aided by the lips, front teeth, tongue, and cheeks. The lips are moved by about twenty muscles, by which they are enabled to grasp and retain the food. At their margin the skin becomes continuous with the mucous membrane lining the digestive cavity.

Mastication is the process by which the food is crushed and broken up into small particles. Its object is to overcome the force of cohesion, by which the particles of the food are held together, and so enable the juices necessary for their solution to permeate them readily.

The organs concerned in mastication are the mouth, teeth, tongue, cheeks, palate, the upper and lower maxillary bones, and certain muscles termed the muscles of mastication.

This process is effected in the mouth, which contains the principal organs of mastication. In order to perform their cutting and bruising operations more effectively the teeth and jaws receive a threefold motion— a vertical movement, by which the food is cut and bruised; an antero-posterior, or backward and forward movement; and a lateral movement, by which the food is more thoroughly triturated. The tongue is an important auxiliary to mastication, continually collecting the food together, and bringing fresh portions under the teeth. The cheeks and palate also help by retaining the food in the mouth. The jaws are put into motion by the muscles of mastication.

The Mouth is an irregularly shaped cavity, bounded in front by the lips, behind by the fauces, above by the hard and soft palates, which separate it from the cavity of the nose, and below by the tongue (Fig. 6). It is lined with a peculiar skin, termed the mucous membrane, which contains a number of little rounded bodies about the size of millet seed, termed conglomerate glands, whose tubes or ducts open into the mouth. These glands supply moisture to the mouth, which prevents its becoming dry and parched, and also helps to lubricate the food.

Fig. 2.—HUMAN TEETH.

Permanent Teeth.—The adult human being is supplied with thirty-two teeth termed permanent teeth, which are arranged in two semicircular arches at the outer edges of the upper and lower jaw-bones. They are inserted into corresponding sockets, or alveoli, in the dental arches (gums) of the jaw-bones. This mode of union, which somewhat resembles that of a nail in a piece of wood, is termed gomphosis. They are retained in their places by vascular tissue, which grasps the neck of the tooth. There are sixteen teeth in each row; each row is divided at its middle line into two equal sets of teeth, each set containing four kinds of teeth (shown in the diagram), as follows, commencing from the middle line :—two incisors, or cutting teeth; next, one canine, or cuspid tooth; then two premolars, small molars, or bicuspids; and lastly, three large molars.

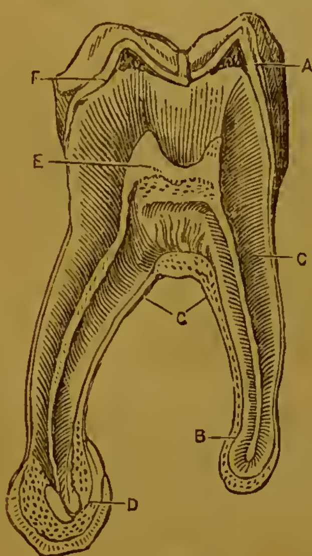
The Incisors, or cutting teeth, are chisel-shaped, being bevelled from the interior, as shown in the diagram. They are used in cutting, and are largely developed in rats, rabbits, and other gnawing animals. They are inserted by one conical root or fang.

The Canine teeth are single-pointed teeth situated next to the incisors. They are largely developed in the flesh-eating animals, and enable them to seize and tear their prey. They are comparatively small in man. The upper canine are called the eye-teeth.

The Bicuspid, or false molar teeth, are double-pointed at the top, and are used in bruising and grinding the food. They are placed between the canine teeth and the large molars. The upper ones have one fang deeply set.

The true Molars are the principal grinding teeth; they have broad square tops, with four or five cusps or points, and two or three fangs or roots. The last molars do not usually make their appearance much before the period of adult age; they have, therefore, been termed wisdom teeth.

Structure of the Teeth.—Each tooth consists of three parts—the crown, or exposed part, which projects



A, Enamel.
B, G, D, Cementum petrosa.
F, C, Dentine.
E, Pulp cavity.
B, D, Fangs.

Fig. 3.—Section of Tooth.

above the gum; the fang, or root, which is buried in the gum; and the neck, or grooved and slightly constricted portion, which separates the crown from the root. It has an internal cavity which contains the tooth-pulp. The tooth-pulp consists of nerves and bloodvessels. The tooth cavity has but one opening, at the base of the tooth, through which the nerves and bloodvessels pass into it.

The mass of the tooth is composed of a very hard tissue closely resembling bone, which is termed dentine. The crown of the tooth is covered by a still harder substance, the hardest substance in the body, termed the enamel. The fang of the tooth is covered with a very thin covering of bone, called tooth-bone, or the *cementum petrosa*. It is principally by this bony covering that the teeth are joined so securely to their sockets.

The Enamel is a hard, polished, bluish-white substance, consisting of little five or six-sided rods or prisms, about 1-4500th of an inch in diameter, placed

Fig. 4.—MICROSCOPIC SECTION OF ENAMEL,
Showing hexagonal rods or prisms arranged endwise.

endways on the surface of the dentine. It is so hard that it will strike fire with steel. It forms a thin layer,

covering the exposed surface of the tooth, giving it additional hardness and durability. When once damaged or broken it is doubtful, from its low vitality, whether it is ever repaired. It is, like glass, a bad conductor of heat, and is very easily cracked by a high or low temperature. Hence very hot or very cold liquids taken into the mouth tend to damage the teeth. When once the dentine of the tooth is exposed, by the destruction of the enamel, the tooth soon begins to decay.

Milk Teeth.—At the time of birth the infant possesses twenty teeth, ten in each jaw, which are perfectly developed, but are completely covered or hidden by the gums. In about seven to ten months these teeth penetrate through the gums, and make their appearance: this is usually known as "cutting the teeth." If the child be strong and healthy, and kept sufficiently in the open air, it very rarely suffers; if, on the contrary, the child is not well, or is not kept out in the fresh air during a sufficient number of hours daily, its nervous system becomes exceedingly irritable, and the child not only suffers much, but is frequently attacked by convulsions and dies. This is one cause of the great mortality of infants at this age. The teeth just described only last during infancy and childhood, being shed from the seventh to the thirteenth year; they are, therefore, termed milk teeth, or deciduous teeth. They are shed because of the growth of the permanent teeth, which, pressing on the roots of the milk teeth, interrupt their nutrition. Their fangs are consequently absorbed, and they drop out. The milk teeth consist, in all, of eight incisors, four canine, and eight molars.

Development of the Teeth.—The teeth do not properly belong to the true skeleton, being develop-

ments from the mucous membrane, and not from the jaw-bones.

A groove is first formed in the mucous membrane, called the dental groove; little papillæ are then developed; partitions, or septa, spring up in the dental groove, separating the papillæ from each other. In this manner the dental groove forms follicles; these follicles close over the papillæ, forming sacs, termed dental capsules; the enclosed papillæ, which contain nerves and vessels termed the pulp, are gradually calcified and converted into dentine; the crown becomes covered with enamel; and the fang, which is latest developing, gradually growing and receiving a

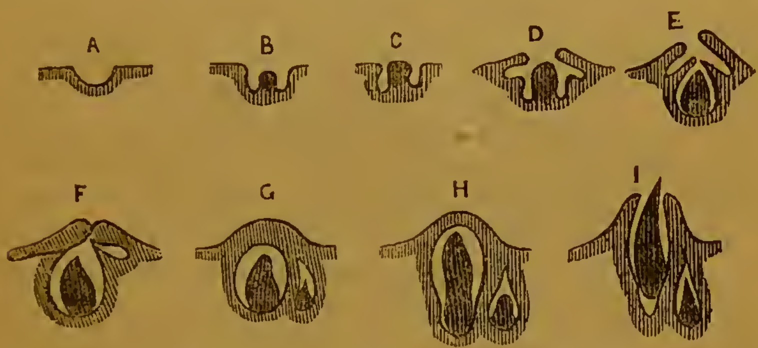


Fig. 5.—Development of Teeth.

A, B, C, D, E, show the formation of the dental groove, papillæ, and opercular (cover) flaps, which close the groove. F, G, H, I, show the formation of secondary cavity (of reserve) and permanent teeth. The cavity of reserve, in which the permanent teeth are formed, is the smaller follicle to the right of the original follicle or dental groove.

covering of cementum, begins to push the crown against the upper portion of the capsule and gum. The continued pressure of the tooth against the gum causes its absorption, and allows the passage of the tooth. The tooth is then, in domestic language, "cut."

The development of the permanent teeth always begins long before the child is born.

Insalivation is the process by which the food is thoroughly incorporated with the saliva, and other fluids, which are poured into the mouth from their respective glands. It proceeds simultaneously with mastication. Its purposes are—(1) to lubricate the food, and thus facilitate the process of swallowing; (2) to render it more permeable by the juices of the stomach; (3) to assist in changing the starchy portions of the food into sugar.

The Salivary Glands.—The spittle, or saliva, is secreted in large quantities by three pairs of glands, termed salivary glands, three of which are placed on each side of the face—the parotid glands, which are situated under the ears, a little towards the cheeks; the sub-maxillary glands, situated under the lower jaws; and the sub-lingual glands, which lie under the base of the tongue, and form a projection in the floor of the mouth, behind the frænum, under the front of the tongue (Fig. 6). The parotid ducts pour the saliva into the mouth by their orifices immediately over the second upper molar teeth. The sub-maxillary ducts discharge their saliva into the mouth by two ducts opening by the side of the frænum of the tongue. The sub-lingual glands have several ducts, opening into the mouth at the side of the lower part of the tongue, between it and the lower jaw. It is calculated, about three pints of saliva per day are secreted by the salivary glands. The quantity required varies with the kind of food. Juicy substances, as well as cooked meat, require 40 to 50 per cent. of their weight of saliva; dry, hard biscuits require as much as 150 per cent., or one-and-a-half times their own weight of saliva; while, on the other hand, some substances, as some juicy fruits,

require as little as 4 or 5 per cent. of saliva. The saliva is poured out in greatly increased quantities, in consequence of reflex action, directly a substance is brought into contact with the tongue, or the walls of the mouth: also in certain cases of mental emotion, excited by hunger or by the odour of food. All have experienced the sensation known as the "mouth watering" at the sight, smell, or recollection of savoury food. Its flow is greatly increased by the movements of mastication; also, to a certain extent, by speaking. Certain medicines and poisons, as mercury, exercise a specific action on these glands, increasing the quantity of the secretion to many quarts per day. Fear and other painful emotions sometimes very greatly diminish the secretion, causing the mouth to become parched and dry.

Properties of Saliva.—The saliva, or spittle, is a clear, colourless, transparent, slightly viscid, and sometimes frothy liquid. It is at first slightly opalescent, from the presence of mucus and of epithelial scales, derived from the mucous lining of the mouth. It contains a peculiar active principle termed diastase, ptyaline, or salivine, which exercises a powerful action on starch, changing it into grape sugar. The saliva of the parotid glands also contains a salt, called the sulphocyanide of potassium.

Deglutition (L., *de*, down, and *glutio*, I swallow) is the process by which the food is forced down the pharynx and œsophagus into the stomach.

The chief organs of deglutition are the mouth, tongue, hard and soft palate, pharynx, and œsophagus or food-pipe.

Let the reader masticate a piece of food, and carefully observe the following stages in the act of swallowing or deglutition, as they proceed in his own person :—

1. The masticated food is mixed with the saliva, and formed into a bolus or ball by the action of the tongue; the tongue then assumes a grooved shape,

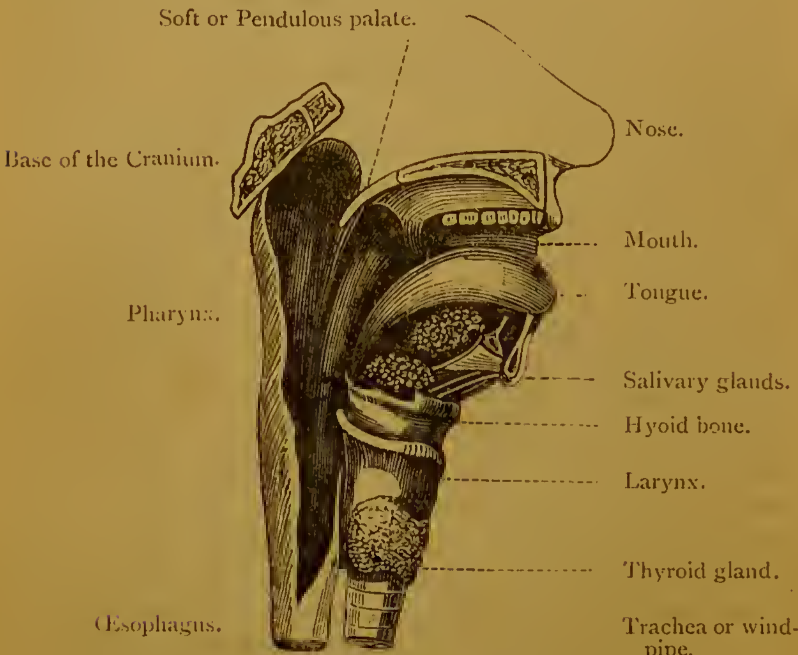


Fig. 6.—Vertical Section of the Throat and Mouth.

and conveys the bolus to the back of the mouth, squeezes it against the hard palate, and obliterates the cavity of the mouth; the soft palate is pushed backwards against the back of the pharynx, which is thus shut off from the cavity of the nose, into which the food would otherwise enter. The larynx is simultaneously drawn under the base of the tongue; the base of the tongue and the food, aided by certain muscles, press down the epiglottis, thus closing the aperture of the windpipe, and preventing the passage of the food into it.

2. The bolus passes from the pharynx into the œsophagus, where it is seized by the middle and inferior constrictor muscles of the œsophagus, which, by a wave-like motion, force it downwards. Simultaneously the tongue resumes its ordinary position, the epiglottis springs up by its elasticity, reopening the trachea, or windpipe, which also returns to its normal position; and respiration, which is interrupted during the first stages of deglutition, is resumed.

3. The food passes into the stomach.

The reader will have observed that the first stage of this process, which is performed in the mouth, is purely voluntary, the second stage is involuntary, though we are perfectly conscious of the presence of the food. and of the action which is proceeding. This stage of the process has therefore been described as automatic, a term applied by physiologists to designate the involuntary but conscious action. The last stage of the process by which the food is passed into the stomach is purely reflex—that is, it is performed involuntarily and unconsciously.

That solid and semi-solid substances do not, in the process of swallowing, fall down the œsophagus by the mere action of gravity, is evident from the difficulty which most persons, at first, experience in swallowing pills. The general impression prevails that a pill is difficult to swallow because it is too large, whereas the real difficulty arises from its being too small. Pills are, in general, so small that the constrictor muscles of the œsophagus can only seize hold of them with difficulty. This is easily proved by the facility with which a small plum or cherry is swallowed, in spite of all our efforts to prevent its passing into the stomach, should we inadvertently allow it to get to the back of the mouth.

When the œsophagus is weakened or paralyzed before death, so that its muscles cannot act, the food falls into the stomach by the mere action of gravity, with a deep sound resembling that of a stone into a well. Man also swallows against gravity when he performs the feat of swallowing in the position described as "standing on his head."

The Pharynx (Gr., *pharugx*, gullet,) (see Fig. 6) is a funnel-shaped sac or tube of membranous muscle communicating at its upper and larger part with the cavities of the mouth and nose, and terminating at its lower end in the œsophagus or food-pipe. It extends from the base of the skull down to the fourth or fifth vertebra of the neck. It is about 4½ inches long. Its upper extremity is about two inches in diameter, and its lower end rather less than one inch in diameter.

It is chiefly composed of three pairs of muscles, three on each side,—the superior, middle, and inferior constrictor muscles. It is lined internally by mucous membrane, and is covered externally with fibrous membrane. It is situated immediately behind the larynx, or top of the windpipe, over the entrance of which all the food must pass before reaching the pharynx. If the larynx be kept open by talking or laughing during the process of swallowing, the food will pass into it, only to be expelled after most inconvenient and violent fits of coughing. It will be observed that the pharynx serves the double purpose of conducting air through the mouth and nose to the larynx, and food through the mouth to the œsophagus. In deglutition the food has not only to be conveyed into the stomach, but to be prevented from passing upwards into the cavity of the nose, or downwards into the windpipe.

The Œsophagus (Gr., *osio*, I shall carry, and *phago*,

I eat), or food-pipe, is the tube commencing at the lower end of the pharynx, and terminating in the cardiac pouch of the stomach (see Figs. 6 and 7). It commences at about the fourth or fifth vertebra, and, after perforating the diaphragm, enters the stomach opposite the tenth dorsal vertebra. The walls of the œsophagus are thick, and consist principally of an outer longitudinal layer of muscular fibre, and a much thinner inner layer of circular muscular fibre. The upper part of the œsophagus contains striped or voluntary muscular fibre ; the lower part is made up almost entirely of involuntary or unstriped fibre. It is lined with mucous membrane, which is well studded with glands.

The sides of the œsophagus wrinkle longitudinally, and collapse or fall together when food or drink is not passing down it. The pharynx, on the contrary, is always open to receive air through the mouth and nostrils.

Suction.—The swallowing of liquids, at least until they have entered the œsophagus, is effected by entirely different means from those which obtain with regard to solid food. Observe what takes place when you drink out of a cup or a glass : you apply your lower lip to the side of the cup, so as to form with it an airtight junction—the tongue filling the whole of the mouth, so as to obliterate its entire cavity,—and the upper being placed in or immediately over the liquid. Simultaneously with this you press your soft palate back against the walls of the pharynx, so as to prevent the air from entering the mouth through the nose. You then withdraw and depress your tongue, and, by means of certain muscles, draw the top of the throat downwards and forwards, by which a vacuum is produced. The air in attempting to rush in presses on the surface of the liquid, and drives it forward into the mouth and pharynx to fill the vacuum thus pro-

duced. A similar operation is performed by the infant when suckling.

Chymification, or Stomach Digestion.—The food, duly prepared by mastication and insalivation, passes into the stomach by its cardiac orifice, and coming into contact with its walls, stimulates them to perform certain mechanical movements, and to secrete and discharge into its cavity a peculiar solvent fluid, termed the gastric juice. A portion of the food contained in the stomach is dissolved by the gastric juice, and passed by absorption through the coats of the veins directly into the blood. Another portion, consisting of starchy matter, which has been converted into sugar by the action of the saliva, is also dissolved and similarly absorbed; but the greater portion is converted into a gruel-like mass termed chyme. The chyme is then driven forward by the mechanical contractions constituting the vermicular motion of the stomach, and passing through the pyloric valve at its lower and smaller end, reaches the duodenum, or first portion of the small intestines, there to undergo further changes, which will be explained under the head of Intestinal Digestion.

The Stomach is a somewhat conical, curved bag or pouch, capable of holding, when full, from three to five pints of food (Fig. 7). It consists of four distinct coats—1, an outer, serous, or peritoneal coat; 2, a middle or muscular coat, consisting of longitudinal, transverse or circular, and oblique muscular fibres; 3, a sub-mucous or areolar coat; and 4, an inner or mucous coat. The first serves to strengthen and protect the organ; the second to perform the vermicular movements necessary to rapid and perfect digestion; the third to attach the mucous membrane to the muscular coat, and form a matrix in which the minute gastric arteries and the nerves break up and ramify

and the fourth, or last, to secrete the various juices by which gastric or stomach digestion is effected.

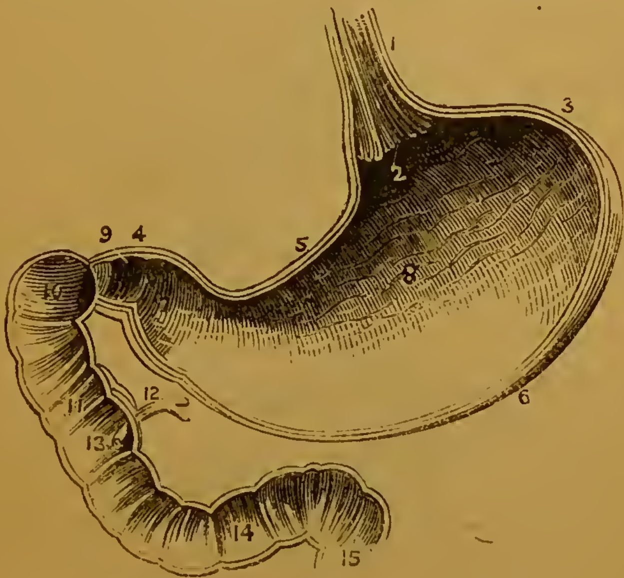


Fig. 7.—Section of Stomach.

1. Œsophagus.
2. Cardiac orifice.
3. Cardiac pouch.
4. Pyloric end or pouch.
5. Lesser curve.
6. Greater curve.

7, 8. Interior, showing *rugæ*, or folds.
9. Pylorus.
10, 11. Duodenum, showing *valvulæ conniventes*.
12, 13. Common bile duct.
14, 15. Intestine (jejunum).

The stomach has two orifices, or openings—the cardiac orifice, by which it communicates with the œsophagus; and the pyloric orifice, by which it communicates with the duodenum. When moderately distended it has an upper concave border, termed the lesser curve; and a lower convex border, termed the greater curve. When the stomach is quite empty its walls collapse, these curves entirely disappear, and it hangs down from the œsophagus. It is slightly con-

stricted or narrowed in the middle by the notch which divides it into a cardiac and a pyloric pouch.

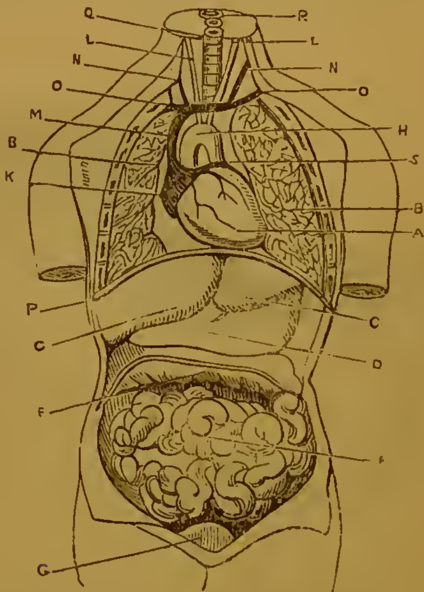


Fig. 8.—Front View of the Organs of the Thorax and Abdomen.

A. Two ventricles of the heart.
B, B. Right and left lung.
C, C. Right and left lobes of liver.
D. Stomach.
E. Transverse colon (large intestine).
F. Small intestine.
G. Bladder.
H. Aorta.
K. Right auricle.
L, L. Right and left carotid arteries.
M. Superior vena cava.
N, N. Right and left jugular veins.
O, O. Right and left sub-clavian veins.
P. Diaphragm.
Q. Windpipe.
R. Œsophagus.
S. Left auricle.

The cardiac pouch, so called from its vicinity to the heart, is the only part of the stomach supplied with oblique muscular fibre.

Situation of the Stomach.—The stomach (see D, Fig. 8) lies across the upper part of the abdominal cavity, its larger or cardiac extremity lying on the left side in contact with the lower surface of the diaphragm (P), and its lesser or pyloric extremity extending a little forward towards the right side underneath the liver (C) as far as the right kidney. Its lower border lies parallel with the transverse colon (E). It is attached to the spleen, which lies at its left or cardiac extremity, by a process of the peritoneum termed the gastro-splenic omentum; to the liver by the gastro-hepatic, or the lesser omentum; and to the colon by the great omentum. These omenta, or apron-like processes of the peritoneum, are seen very beautifully in the newly killed sheep displayed in the butchers' shops, presenting the appearance of delicate transparent membranes covered with a network of fat, the meshes of which are more or less close.

The upper end of the stomach is attached to the diaphragm at the point at which it is penetrated by the œsophagus; its lower end is very moveable, and is connected with the duodenum, which is fixed to the posterior wall of the belly. Being attached chiefly by its two extremities, it possesses considerable mobility, aud readily adapts itself to all the changes of position required by the varying amounts of food it may contain, and to the exigencies of bodily action.

The Serous Coat of the Stomach is derived from the peritoneum, or lining membrane of the abdomen, which invests the stomach, and gives off the various processes or omenta previously referred to. It consists of a layer of areolar tissue covered by basement membrane, which is lined with a single layer of flattened hexagonal epithelial cells.

The Muscular Coat of the stomach consists of

three layers of unstriped or organic muscular fibre—1, an outer or longitudinal layer; 2, an inner, transverse, or circular layer, much thicker than the preceding; 3, an oblique layer. The layer of oblique muscular fibre is only found at the larger or cardiac end of the stomach, and lies under the transverse layer, and in immediate contact with the mucous coat. The muscular coats of the stomach are continuous with those of the œsophagus and intestines.

The Mechanical or Vermicular Action of the stomach is performed through the agency of the muscles just described, as follows:—1. At the close of each act of swallowing the lower muscular fibres of the œsophagus contract with such force as to entirely obliterate the cardiac orifice: this constriction lasts a few moments. 2. Very shortly, in a few moments after food has been received into the stomach, a slight constriction of the transverse fibres commences at the cardiac end of the stomach: this constriction is gradually transmitted to the pyloric end, becoming more rapid and powerful after passing the notch which divides the stomach into the two pouches: the constriction having arrived at the pylorus a moment of relaxation follows, after which the action is repeated.

Towards the end of the process the stomach becomes very much constricted at its notch, producing what is described as the hour-glass constriction, and the muscular action of the stomach is almost entirely confined to the pyloric pouch, the cardiac pouch remaining nearly if not quite inactive.

Dr. Beaumont found that the food made a complete revolution round the walls of the stomach, passing from the cardiac to the pyloric end and back again in from one to three minutes. The mode in which this revolution is effected is most probably the following:—A

constriction of the stomach commences at the cardiac orifice, becoming more powerful as it proceeds towards the pylorus. This constriction may be compared to a ring travelling from the large to the small end of the stomach (Fig. 9), and pushing the food in contact with the walls of the stomach before it; thus establishing a peripheral or outer current of food, moving towards the pylorus.

The food, having arrived at the pyloric or closed end of the stomach, and being still pushed from behind and unable to move forward, is forced into the line of least resistance, and commences a return or backward movement in the direction of the axis of the stomach—that is, of the central line joining its cardiac and pyloric orifices. In pursuing this backward direction the food is returned to the cardiac orifice, again to repeat a similar series of movements, until it is sufficiently dissolved to pass through the pyloric valve, or until this valve becomes wearied of further resistance to its progress. In this way a peripheral forward and an axial return current of the food are set up by the vermicular motion of the stomach.

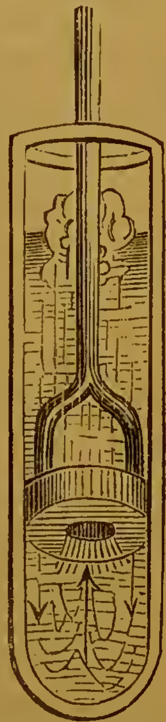


Fig. 9.—Diagram illustrating Gastric Peristalsis.

The perforated piston or ring is supposed to be moving downward in a closed tube containing liquid, thus producing an axial upward and a peripheral downward current.

The Mucous Coat of the Stomach, which forms the fourth or innermost coat, derives its name from the circumstance of its being constantly covered by a thin, transparent, slimy, slightly viscid fluid termed mucus. The mucous, sometimes termed the villous coat of the stomach, is by far the most important and interesting of the four gastric membranes. It has a soft, velvety appearance, and is of a pinkish white

Fig. 10.—Mucous Membrane of the Stomach.

colour when the stomach is empty; but when the stomach is full, during digestion, it is of a brilliant red hue. Its surface is greater than that of the other membranes, in consequence of which it collects in *rugæ* or *plicæ* (folds or wrinkles) when the stomach is empty. These folds in general run longitudinally; they disappear when the stomach is fully distended with food. The rugæ are familiarly seen in tripe. The mucous coat consists of—1, a layer of basement membrane; 2, an inner layer of epithelial cells. Its surface is greatly increased by the gastric follicles, or tubuli, which are simply foldings in, or recesses in the surface of the membrane: the number of these tubuli, or follicles, is estimated at upwards of 5,000,000. Their principal function is supposed to be the secretion of the gastric juice. If the mucous membrane be

stretched, and its free surface be carefully examined with a magnifying glass, it is seen to be covered with small shallow, polygonal pits or depressions, termed alveoli, into the floor of each of which the mouths of six or eight of the stomach or gastric tubuli open. (See Figs. 10 and 11.) Rudimentary villi exist towards the pyloric end of the stomach. In addition to the gastric tubuli or glands, its surface is studded, though somewhat sparingly, with lenticular glands (Fig. 15, g), similar to those of the intestines: their function has not yet been determined. The mucous membrane is doubled or folded into a ring at the pylorus, forming the pyloric valve.

The Gastric Tubuli, or Follicles, are minute vertical tubes in the mucous membrane; they are about 1-25th of an inch in length, and 1-350th of an

Fig. 11.—Gastric Follicle.
Showing columnar epithelium in middle and upper part of tube, and glandular epithelium in lower part of tube, adhering to wall of basement membrane.

inch in diameter. Their length is thus about ten or twelve times their diameter. They consist of an outer wall of fine basement membrane, and an inner lining of epithelium, which is glandular or spheroidal at the bottom of the follicle, and columnar towards its upper portion. The glandular epithelium filling the lower part of the follicles consists of oval nucleated cells, the largest of which are about 1-1,200th of an inch in diameter. The gastric follicles have in general a cylin-

drical shape, are rounded and closed at their bases, and are slightly expanded at their upper and open extremities or mouths. They are, however, very frequently slightly expanded at their lower extremities, having a somewhat flask-like shape, and they not unfrequently split up or divide, at their lower or closed extremities, into three or four separate microscopic pouches or sacs. They are embedded in the meshes of the sub-mucous areolar tissue which forms their matrix. The gastric follicles are now supposed by most modern physiologists to secrete pepsin, the peculiar organic principle of the gastric juice.

Capillaries of the Gastric Follicles.—Two systems of capillary network may be described as belonging to the gastric follicles—1, a parietal network, which surrounds the walls of the tubuli, or follicles; 2, a superficial network, which ramifies through the surface of the mucous membrane, and occupies the interspaces or ridges between the mouths of the follicles, and the capillaries of which encircle these minute orifices.

The minute arteries, about 1-1,800th of an inch in diameter, from which these capillaries are derived, ramify in the sub-mucous areolar tissue, pass up vertically between the exterior walls of the follicles, giving off—1, the parietal network which surrounds the gastric tubuli; then forming, 2, the superficial capillary network previously described; 3, the radicles of the veins, formed by the union of the superficial capillaries, at first about 1-1,500th of an inch in diameter, which again uniting, produce, by repeated junctions, minute venous branches, 1-500th to 1-400th of an inch in diameter. These veins pass vertically down between the follicles, through the substance of the mucous membrane, to the sub-mucous areolar tissue, in which they join the larger venous trunks which ramify there.

As a consequence of these arrangements the blood takes the following course during its circulation through the mucous membrane of the stomach :—1, it passes from the arteries in the sub-mucous areolar tissue (*a*, Fig. 12); 2, up the minute parietal capillaries (*t*) surrounding the gastric follicles; 3, into and through the

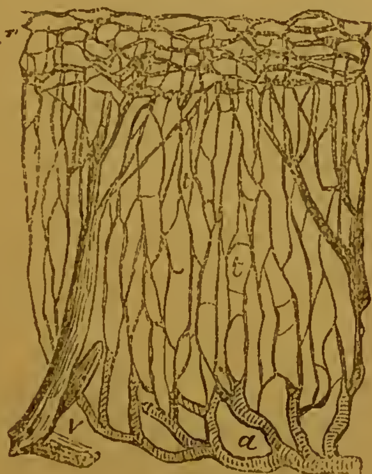


Fig. 12.—CAPILLARIES OF GASTRIC FOLLICLES.
a. Small artery of plexus in sub-mucous tissue.
t. Parietal capillaries around walls of follicles.
r, r. Larger capillaries, forming superficial network on ridges separating mouths of follicles.
v. Veins formed by branches of superficial network, ending below in sub-mucous venous plexus.

larger superficial capillaries (*v*) encircling the mouths of the tubuli; 4, into and down the veins between the tubuli; 5, into the veins (*v*) sub-lying the mucous membrane, by which it leaves that membrane.

These veins collect the blood from the stomach, and ultimately pass it into the portal vein. The portal vein distributes it through the liver, where it affords bile. It is then collected and passed out of the liver by the hepatic vein, which discharges it into the vena cava, by which it is returned to the heart.

The Gastric Juice (Gr., *gaster*, the stomach),

when pure, is a clear, limpid, transparent, colourless or pale straw-coloured, structureless liquid, having a peculiar odour resembling that of the blood, and a slightly saline and sour taste, which is poured out of the mucous or lining membrane of the stomach during digestion. It has a slightly acid reaction, reddening blue test-paper, effervesces slightly with alkaline carbonates, and does not coagulate on being heated. It possesses powerful antiseptic qualities, and is capable of arresting putrefaction, as shown in the digestion of *high* game.

At a temperature of 90° to 100° F. it possesses great solvent power over the protein or albuminous compounds, which it rapidly dissolves, reducing them all to a compound termed peptone, which possesses certain common properties, whether formed by the solution of albumen, fibrin, or gluten. At a temperature of 120° and upwards, also at the ordinary temperature of the atmosphere, its solvent power almost entirely ceases. The gastric juice exerts but little or no power over the starch or gum of vegetable food. It sometimes dissolves or erodes through the coats of the stomach, especially in cases of sudden death by accident after a meal, and while digestion is proceeding; but it is said to exert little or no solvent power over living bodies, which accounts for the presence of living forms in the stomach.

Composition of Gastric Juice.—It is difficult to determine the exact composition of gastric juice. It is rarely if ever found pure, being almost constantly in a state of admixture with mucus, saliva, or other digestive fluids. It is also doubtful whether pure gastric juice has a definite chemical composition; it most probably varies, more or less, in composition according to the requirements of the food and the state of the system. The following table indicates the general plan of the composition of true gastric juice:—

Gastric juice { Water.
Hydrochloric and lactic acids.
Salts, such as chloride of sodium, &c.
An organic ferment (PEPSIN).

Chyme is a soft, greyish, or porridge-like, slightly acid substance, produced by the action of the gastric juice and the saliva on the masticated food which has been submitted to the action of the stomach. It varies more or less in colour, consistence, and appearance, according to the nature of the diet. Chyme consists principally of the fatty and the indigestible portions of the food, of the starchy elements which have not yet been converted into sugar by the action of the saliva, possibly some sugar, and more or less of the peptone, or dissolved proteinous substances that have escaped absorption (by osmosis) through the coats of the stomach into the veins. When examined by a microscope, muscular and vegetable fibre, starch grains, liquefied fat, and minute strings of tendon are plainly visible.

Peptone is the term applied to the solution of the albumen, fibrin, casein, or other proteinous compounds in gastric juice. It is said to be identical in character and properties, from whatever albuminous or proteinous compounds it may have been formed. It resembles albumen in some of its properties, and was termed "incipient albumen" by Dr. Prout, but it differs from albumen in many of its most important characteristics. It is not coagulated by boiling or acids, and is easily absorbed and assimilated by the system.

Artificial Digestion.—Procure three small bottles; introduce into each a small quantity of artificial gastric juice, made by dissolving pepsin in water slightly acidulated with hydrochloric acid. Also procure three small pieces of lean flesh-meat of equal weights. Mince one of the three weighed portions of meat very

finely. Place the undivided portions of the meat in bottles 1 and 2, and the finely divided portion in bottle 3. Allow bottle 1 to remain perfectly quiet at the natural temperature of the atmosphere. Heat bottle 2 and its contents to 98° or 100° F. by means of a water bath, but be sure it is kept in a state of perfect quiescence, that temperature being maintained during the whole of the experiment. Warm bottle 3 and its contents to the same temperature (98° or 100° F.), but instead of keeping it in a state of quiescence keep it well agitated by continuous shaking; taking care that its temperature remains at the same point. Examine the contents of the bottles from time to time. In about one and a half to two hours the minced meat in bottle 3 will be found to be completely dissolved or chymified. The contents of bottle 2, which have been kept warm, will be found to be but slightly changed at the end of an hour, though the process of chymification will have fairly commenced; in about three hours nearly one-half of the meat will have been dissolved, but the complete chymification will not have been effected until nine to twelve hours after the commencement of the experiment. If the contents of bottle 1 be now examined they will be found to present no signs of solution or chymification; the meat will be found slightly softened by the maceration, but no more dissolved than if kept in water, especially if it were slightly acidulated, during the same period of time. Dr. Beaumont performed similar experiments to those just described by means of the natural gastric juice, obtained from the stomach of St. Martin. He also compared the results with those of natural digestion as it proceeded in his stomach. Other investigators have obtained the gastric juice necessary for their experiments by various devices. One ingenious method

consists of inserting small pieces of sponge into small hollow perforated metal balls, attaching the balls by string, and giving them to men and to inferior animals to swallow. The mechanical irritation of the ball against the mucous coat of the stomach causes it to pour out the gastric juice, which is absorbed by the sponge. The ball is then drawn out of the stomach by means of the string, the sponge removed, and the gastric juice squeezed out of it. The operation is then repeated until a sufficient quantity of gastric juice is obtained. If the quantity of meat in the bottle be too great, it will not dissolve unless more gastric juice be added.

The following inferences in relation to natural digestion may be drawn from the results of these experiments:—1. The drinking of large quantities of cold water, beer, or other liquids, by reducing the temperature of the stomach and the gastric juice below its natural standard, materially checks digestion. This effect is still further increased by the dilution of the gastric juice. 2. The swallowing of the food without due mastication obstructs and prolongs the process of gastric digestion, and materially increases the labour of the stomach. 3. The eating of excessive quantities of food not only retards the digestion of the actual excess consumed, but prevents the complete and perfect digestion of every portion of the entire quantity of food partaken of; so that a small quantity of food, well digested, would afford much more real nutriment than a large excess, which is necessarily ill digested, because of the insufficient quantity of the gastric juice supplied by the stomach.

Dr. Beaumont inferred, from the results of some of his experiments, that the whole of the gastric juice was supplied by the stomach within twenty to forty minutes of the commencement of the process of digestion.

What Dr. Beaumont saw in the Stomach.—Our most accurate knowledge of what takes place in the stomach is derived from the observations of Dr. Beaumont, of America. In 1822 a healthy young Canadian, named Alexis St. Martin, met with a gunshot accident, a portion of his lungs, diaphragm, ribs, and outer integuments being blown away, and a perforation made into his stomach. He became a patient of Dr. Beaumont, and in about a year from the time of the accident, he, through skilful treatment and the possession of a sound and unimpaired constitution, had entirely recovered. The perforation in his stomach, however, still remained—about 2½ inches in diameter. At first, even after recovery, the food escaped through this aperture, unless it was closely covered; ultimately a sort of valve was formed by a fold of the mucous membrane of the stomach. This fold prevented the contents of the stomach escaping externally, but admitted of being easily opened by the finger when pushed from without, exposing the inside of the stomach and its contents to the view of the observer. Dr. Beaumont, during a period of two years, conducted a very extensive series of experiments on digestion, on the person of this St. Martin, who was in a high state of health.

On pushing back the valve referred to in the stomach of St. Martin, it was observed—1, that when his stomach was empty, its interior was of a pale pinkish white colour, and did not contain any gastric juice; 2, that on the entry of the food or any mechanical body, its walls immediately became charged with blood, assuming a much deeper pink or red colour, and that little globules of gastric juice, which trickled down and mixed with the food, immediately began to ooze out of its walls; 3, that on the food entering the stomach, a gentle onward motion, the vermicular

motion, was immediately set up by its walls, the motion becoming more rapid and powerful as digestion proceeded; 4, that the food was gradually converted into a gruel-like, pulpy mass termed chyme, which disappeared through the pyloric orifice. Dr. Beaumont further observed, that though the exudation of gastric juice immediately followed the introduction of any solid body, yet it soon ceased if such body did not act as food. In the course of his observations he was led to infer, that the quantity of gastric juice secreted was not determined by the quantity of food taken, but by the quantity of food required by the wants of the system; so that the surplus food, after fatiguing and irritating the stomach and intestines, and producing more or less feverishness and restlessness, was passed out of the body undigested. He also observed, that in certain states of the system, more particularly in fever, the mucous coat remained red and dry, and incapable of supplying gastric juice, thus showing the uselessness of attempting to administer solid food in cases of fever. He also noticed the effect of various mental emotions—as anger, fear, and anxiety—in disturbing the state of the mucous membrane of the stomach, vitiating its secretions, and interrupting or injuring its functions.

Dr. Beaumont always found, that after St. Martin had been indulging in spirits for a day or two, though not to a degree usually termed excessive, his stomach became covered to a greater or less extent with dryish red-looking patches. In these cases St. Martin was himself entirely unconscious of any deterioration in his health.

The Bloodvessels of the Stomach.—The arteries of the stomach are derived from the cœliac axis. This vessel is given off from the aorta opposite the first lumbar vertebra, forming a short, thick trunk

about half an inch long, which divides into three large branches—the gastric artery, which supplies the stomach; the hepatic artery, which supplies the liver; and the splenic artery, which goes to the spleen.

The gastric artery, after leaving the cœliac axis, divides into two branches, which pass nearly horizontally, right and left, along the upper and lesser curvature of the stomach. These branches give off numerous smaller arteries, which pass vertically down the walls of the stomach, and anastomose with the vertical branches given off by the right and left gastro-epiploic arteries, which pass below the stomach, taking a generally horizontal direction, and following its lower and greater curvature.

The right gastro-epiploic artery (Gr., *epiploon*, the caul) is derived from the hepatic artery. The left gastro-epiploic artery originates in the splenic artery. These arteries pass along the lower and greater curvature of the stomach—the former from the right, the latter from the left,—and anastomose or join each other so as to form one continuous vessel. They give off numerous branches to the stomach and adjacent parts.

The arteries and veins of the stomach are exceedingly tortuous, and are very loosely connected with its walls. They therefore very readily adapt themselves to any position or degree of distention of that organ.

The smaller arteries and veins form two flattened networks, which lie in the meshes of the areolar submucous tissue, and completely encase the stomach within their vascular structure.

The gastric veins, in general, correspond with the arteries. They empty themselves into the portal vein, which distributes the venous blood from the organs of digestion through the substance of the liver. for the purpose of bile-making.

Lymphatics of the Stomach.—The stomach is supplied with two sets of lymphatics—a superficial set, consisting of smaller vessels which lie immediately outside the muscular coat and beneath the peritoneum; and a larger and deeper set, which ramifies in the submucous coat. The lymphatics of the stomach anastomose very freely with those of the adjacent organs.

Nerves of the Stomach.—The stomach is very abundantly supplied with nerves from the sympathetic and the cerebro-spinal system. The sympathetic nerves are derived from the semilunar ganglia and the solar plexus.

The cerebro-spinal nerves supplied to the stomach consist of the right and left terminal branches of the pneumo-gastric nerve. The right nerve is distributed to the posterior surface, and the left nerve to the anterior surface of the stomach.

When these nerves are divided the stomach loses the power of performing its muscular movements. They would therefore appear to be the motor nerves of the stomach. The experiments of Dr. John Reid would appear to prove that it is possible to sever the pneumo-gastric nerves of dogs without stopping the secretion of the gastric juice. Several dogs on whom he performed this operation continued to live a considerable period after its performance, when the necessary care and attention were given to their feeding.

The stomach is most intimately connected by sympathy with the rest of the system. This is due to its abundant supply of nerves. A sudden blow on the stomach, especially after a full meal, when it is somewhat distended, will sometimes produce death, even when no apparent injury is done to the part struck. Death is, in this case, probably due to the nervous shock.

Osmosis (Gr., *osmos*, impulse) is the term applied to

the process by which two liquids separated by an intervening membrane, or a porous solid, penetrate or traverse its substance, and mix together on its opposite side.

EXPERIMENT.—Procure a wide-mouthed glass funnel, with a long stem of small bore; tie a piece of bladder over the wide opening of the funnel; invert it, and fill the body of the funnel and a portion of its stem with alcohol; then place it in a tumbler or tall glass jar of water, so that the water in the tumbler and the spirits in the tube shall stand at the same level. (Fig. 13.) The liquid in the interior of the funnel will gradually rise, against gravity, until at last, if it be left a sufficient time, the tube of the funnel will be entirely filled, and the liquid will run over. In this case the water from the exterior vessel passes through the substance of the bladder into the funnel. Simultaneously a minute and almost inappreciable quantity of alcohol passes in the opposite direction from the funnel into the water in the jar. A similar action also takes place if a solution of sugar be substituted for the alcohol. If, however, a film of collodion be substituted for the animal membrane the action is reversed, and the sugar or the alcohol passes out of the funnel into the water contained in the tumbler.

Fig. 13.

Endosmose (Gr., *endon*, within, and *osmos*, impulse) is the term applied to that variety of osmosis in which the fluid passes into the vessel.

Exosmose (Gr., *exo*, outside; *osmos*, impulse) is applied to that form of osmosis in which the fluid passes out of the containing vessel.

Liquid Diffusion.—If a tall glass jar be nearly filled with water, and a heavier solution be very carefully introduced into the bottom of the jar, so as not to disturb or mix the fluids, the heavier solution will gradually diffuse through the lighter one, and rise, against gravity, to the top of the jar, until at last the two liquids will be thoroughly mixed. This phenomenon is termed "liquid diffusion," and different liquids possess this power of diffusibility in very different degrees, but the same body always possesses the same diffusibility under the same circumstances.

INTESTINAL DIGESTION, AND THE LARGE AND SMALL INTESTINES.

Intestinal Digestion.—The chyme, or partially digested food, leaves the stomach by the pylorus (5, Fig. 14) and enters the intestines. It there meets with certain fluids secreted by the intestinal mucous membrane, the liver, and the pancreas, by the action of which the process of digestion is completed. This part of the process is designated intestinal digestion, or chylification.

General Outline of Intestinal Digestion.—1, the chyme on leaving the stomach enters the duodenum (6), or first portion of the small intestines, in a decidedly acid state; 2, in the duodenum it meets with certain alkaline fluids, consisting chiefly of the bile, and the pancreatic and intestinal juices, by which its acid properties are neutralized, and its fatty portions converted into a kind of emulsion, by which they are rendered partially soluble, and fitted for absorption by the lacteals in the form of chyle. The conversion of the starchy portions of the food into

sugar is also completed ; 3, the contents of the intestines are pushed slowly onwards by the peristaltic movement of their walls ; 4, the chyle and other nutritious substances are gradually removed from the intestines by absorption through the lacteals and the veins during the onward passage of the aliment ; 5, the indigestible and useless portions of the food, mixed with more or less of the bile, intestinal juices, and

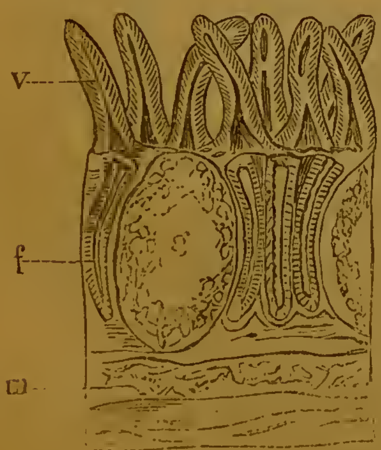
Fig. 14.—ALIMENTARY CANAL.
Showing lower end of œsophagus, stomach, and large and small intestines.

mucus, having arrived at the extremity of the rectum, or terminal intestine, by the action of peristalsis, are expelled from the system by the act of defecation, the nutritious elements of the food having, in healthy digestion, been previously removed by absorption.

The Large and Small Intestines.—The bowels or intestines, which are contained in the cavity of the abdomen, consist of a tubular continuation of the alimentary canal. (See Figs. 8, 14, and 15.) They are comparatively short in carnivorous or flesh-eating animals, but long in herbivorous or vegetable-feeding animals. In man and the monkey tribes, which are omnivorous (live on a mixed diet of animal and vegetable substances), they are of intermediate length.

In the human being they are about five times the length of the body. They are divided into large and small intestines. The small intestines, which are connected with the pyloric end of the stomach, are about 20 feet long and $1\frac{1}{4}$ inches in diameter. They form about 5-6ths of the entire length of the intestines.

Fig. 15.—Vertical Section of Coats of Small Intestine.



Showing mucous coat, with—

v. *Villi* (greatly exaggerated).
f. *Lieburkühn's follicles*, resting on sub-mucous membrane.
g. *Lenticular* (Peyer's) glands, with their lower ends embedded in the sub-mucous membrane.
m. Muscular coat, showing inner transverse, and outer longitudinal layers of muscular fibre.

The outer serous coat has been dissected off.

The large intestines are about 5 feet long, and 2 to 3 inches in diameter; they are connected with the end of the small intestines, which opens into the former by a valve of peculiar construction. The intestines, like the stomach, consist of four coats,—an external serous, a middle or muscular, an areolar or sub-mucous, and an inner or mucous coat. The small intestines are divided into three portions—the duodenum, the jejunum, and the ileum. The large intestines are also divided into three portions; viz., colon, cæcum, and rectum.

They are abundantly supplied with nerves, arteries, veins, and lymphatics, or absorbents. The entestines are surrounded by a serous membrane termed the peritoneum. The small intestines are completely enclosed by a portion of this membrane, termed the mesentery, which is attached to the vertebral column, and helps to retain them in their proper place. Large quantities of adipose tissue, or fat, which serves the double purpose of safely packing the intestines and protecting them from cold and injury, are distributed in different parts of the abdominal cavity. This fat sometimes increases in quantity to such an extent as to produce great inconvenience, as in extreme corpulence, where, by its pressure on the adjacent organs, it seriously interrupts the circulation, producing a partial strangulation.

The inner surface of the small intestines is nearly covered with minute thread-like processes termed villi; it is also studded with numerous glands, viz., the duodenal glands, or the glands of Brunn; the intestinal tubuli, or follicles of Lieburkühn; and the lenticular glands, which are generally distributed in clusters termed Peyer's patches. (See Figs. 15 and 16.)

The large intestines are quite smooth, being destitute of villi; but their inner surface is studded with intestinal follicles and solitary glands. The small intestines

are gathered into folds or convolutions by the mesentery, and the large intestines into saccules or pouches by the longitudinal muscular bands attached to their outer walls. The intestines possess three apertures or openings—the pyloric aperture, by which the chyme enters; a lateral orifice in the duodenum, by which the bile and pancreatic juice enter; and a terminal aperture—the anus, at the lower extremity of the rectum, by which the fæces and undigested food are expelled. The latter extremity is surrounded by a circular ring of muscle termed the sphincter ani, which, by its continuous contraction under the influence of the spinal cord, closes the terminal aperture of the canal, and, under ordinary circumstances, prevents the escape of the fæces without the permission of the will.

The Cavity of the Abdomen, which is the largest cavity in the body, occupies the lower region of the trunk. It is bounded above by the diaphragm, which forms its roof; at its base by the pelvis; in front and at its sides by the lower ribs and abdominal muscles and tendons; and behind by the vertebral column and the posterior abdominal muscles. It contains the principal organs of digestion, nutrition, and excretion, including the stomach, large and small intestines, the liver, pancreas, spleen, kidneys, and bladder; also segments of the trunk of the aorta and the vena cava, which traverse it perpendicularly. (See Fig. 8.) It is lined internally by a serous membrane termed the peritoneum. The inner surface of the muscles forming the walls of the abdomen is also lined by a layer of fasciæ. The interior organs are retained in their places chiefly by the pressure of the abdominal muscles and their broad tendons. In cases of excessive muscular exertion, as in wrestling, and lifting heavy weights,

it sometimes happens that the walls of the abdomen give way, and a portion of the bowel is extruded or forced out of its natural cavity. This constitutes hernia or rupture. Wrestlers, and those accustomed to labour requiring the excessive exertion of the abdominal muscles, frequently wear tight or elastic belts, to strengthen the abdominal walls and enable them to resist this dangerous tendency.

The Peritoneum (Gr., *peri*, about, and *teino*, I stretch) is a serous membrane which lines the entire cavity of the abdomen, and is reflected over the various organs contained in it, so as to furnish them with a more or less complete external covering in addition to their own proper coats. It consists of an inner layer of scaly or squamous epithelium, resting on basement membrane, supported by a thick layer of condensed areolar tissue, which forms the bulk of its substance.

Its inner or free surface is smooth, and is moistened by a small quantity of serous fluid, which lubricates it and lessens its friction with the surfaces of the adjacent organs. When this fluid is secreted in morbid quantities it accumulates in the abdomen, constituting the disease termed ascites (Gr., *asros*, a leathern bottle), or dropsy in the abdomen. Its attached surface is rough, being formed of loose sub-peritoneal areolar tissue. The parietal portion is loosely attached to the fasciæ of the muscles forming the inner walls of the abdomen, and still more loosely to the diaphragm. It gives off three broad processes termed omenta (L., *omentum*, the caul), viz.—the lesser or gastro-hepatic omentum, which extends between the liver and the upper part of the stomach; the great or gastro-colic omentum, consisting of four broad folds, which descends from the stomach, forming a layer in front of the small intestines, and also partially enclosing the colon; and the gastro-

splenic omentum, which connects the concave surface of the spleen with the large end of the stomach.

The great omentum, during health, always contains fat, which protects the intestines from the cold, and tends to facilitate their movements on each other during their peristalsis.

Other processes of the peritoneum which serve to support the liver, spleen, and bladder, are termed ligaments (L. *ligo*, I bind).

The Mesentery (Gr., *mesos*, middle, and *enteron*, an intestine) is that portion of the peritoneum which encloses the small intestines and attaches them to the spine. Its root, which is attached to the vertebral column, is about six inches long; while its intestinal border, only four inches from the root, is about twenty feet long. The gathering of the small intestines into convolutions is due to this arrangement.

The Pylorus (Gr., *pulorus*, a gatekeeper) is a gateway by which the chyme leaves the stomach. (See 9, Fig. 7.) It was formerly regarded as a valve, endowed with a peculiar sensibility by which it distinguished the chyme or partially digested food, and permitted it to pass, refusing permission to the passage of other substances until wearied out. But modern physiologists describe it as a sort of filter or strainer, through the minute central aperture in which the more fluid and homogeneous portions of the food or other substances are pressed by the mechanical contractions of the stomach. When the stomach is nearly empty the pyloric contraction ceases, and the undigested food and other bodies, as marbles, pass into the intestine.

The pylorus consists of an inflection or reduplication of the muscular coat and mucous membrane, which form a kind of ring or circular fold at the small end of the stomach. The mucous fold is surrounded by a

thick layer of transverse circular muscular fibre, which also contains a few longitudinal fibres, and is derived from the ordinary muscular layer of the stomach. This sudden thickening of the transverse muscular coat forms a kind of sphincter muscle, which is sometimes described as the pyloric sphincter.

The Duodenum (L., *duodeni*, twelve), or first portion of the small intestine, commences at the pylorus and terminates at the jejunum. (See Figs. 7 and 14.) It is about ten inches in length, and forms the widest and broadest portion of the small intestines. It forms a curve, somewhat like that of a horseshoe, the concavity of which receives the right end of the pancreas; and has an ascending, transverse, and descending portion. It has no mesentery, and is only partially covered by the peritoneum. The common bile duct, and the pancreatic duct, perforate the descending portion very obliquely a little below the middle. Its inner surface is covered by mucous membrane, containing glands, which are very numerous in its upper part, Lieberkühn's follicles, villi, which are very numerous in its lower two-thirds, solitary glands, in its lowest third, and valvulæ conniventes, which are well developed in its inferior half. The chyme here becomes mixed with the bile and pancreatic juice, discharged through the orifice just described. The first or ascending portion of the duodenum is usually found, after death, stained with bile.

The Jejunum (L. *jejunus*, empty) is the second portion of the small intestine; it derives its name from the circumstance that it is usually found empty in the dead body. (See 7, Fig. 14.) It forms the upper 2-5ths of the small intestines from below the duodenum, with which it is connected. It commences at the duodenum and terminates at the ileum. It pos-

sesses no special characteristics by which it may be absolutely distinguished from other portions of the small intestines; the division made by physiologists, though convenient, is therefore mainly an artificial one. The jejunum is a little larger than the ileum, its coats are a little thicker, and its colour a little deeper. It is well studded with Lieberkühn's follicles, villi, and solitary glands. Its *valvulæ conniventes* are also larger and better developed than those of any other portion of the intestines. It chiefly occupies the umbilical and left iliac regions of the abdomen.

The Ileum (Gr., *eileo*, I twist) forms the third, terminal, and narrowest portion of the small intestine; it terminates in the cæcum, the aperture being guarded by the ileo-cæcal valve. (See 8, Fig. 14.) It is studded with crypts of Lieberkühn, solitary glands, and well-developed villi, which are, however, less numerous than in other parts of the small intestine. The valvulæ conniventes gradually diminish in numbers, and ultimately disappear towards the end of the ileum. It is also less vascular than the jejunum. It occupies the umbilical, hypogastric, right iliac, and occasionally the pelvic regions of the abdomen.

The Intestinal Villi (L., *villus*, a hair) consist of slender papillæ, or short thread-like processes

Fig. 16.—Inner Surface of Intestine (Ileum).

Showing mouths of follicles; Peyer's glands surrounded by mouths of follicles; and villi.

which are attached vertically to the inner wall of the alimentary tube (see Figs. 15 and 16).

The villi are most numerous in the duodenum and the upper part of the jejunum, where they are so close as nearly to cover the inner wall of the intestine ; but they are much less numerous towards the end of the jejunum and the ileum. They are spread over the whole surface of the small intestines up to the ileo-cæcal valve. Dr. Brinton suggests that their form, situation, and function entitle them to be termed the intestinal or chyliferous papillæ.

Structure of a Villus.—Each villus is of a somewhat flat and triangular shape, and is about 1-30th to 1-12th of an inch long; its breadth is about 1-5th, and its thickness about 1-10th of its height. It consists

Fig. 17.—A Villus.
Diagram exhibiting the structure of a villus.
A. Outer layer of columnar epithelium.
B. A single cell.
C. Basement membrane.
D. Capillary plexus.
E. Commencement of a lacteal.

externally of a covering of columnar epithelium, attached to a lining of basement membrane. The interior of the villus contains a network of capillary

vessels, and a central lacteal, which are supported by a granular matrix. (See Fig. 17.)

The Lacteals (L., *lac.*, milk), in the centres of the villi (Fig. 17, E), most probably consist of single club-shaped tubes of structureless basement membrane. Some have described each central lacteal as originating in a microscopic network of vessels; but this appearance is attributed by other writers to optical illusion. The diameter of the central lacteal is about 1-6th of that of the villus. These lacteals are supposed to absorb the chyle by the action of endosmosis. They are much expanded about five hours after a meal, being full of a white opaque fluid, the chyle; at most other times they are empty, and almost invisible. (See Fig. 20.)

The Capillary Networks of the villi consist of capillaries about 1-3,000th of an inch in diameter. Each plexus is derived from a minute artery (see Fig. 18), which enters the base of the villus and imme-

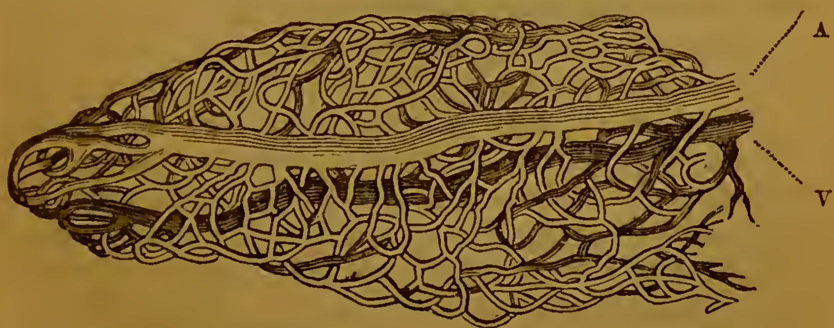


Fig. 18.—Capillary Plexus of a Villus.
Highly magnified, showing—
A. Artery which breaks up and forms the capillary network.
V. Vein, formed by the junction of the venous capillaries. (The veins and venous capillaries are shown by the shaded portions of the diagram.)

diately divides, giving off the branches which compose the network described. Their meshes are exceedingly

close; their length is about five times their width. These capillaries are exceedingly tortuous. The veins commence at the termination of the arteries in the upper part of the villi, and run into each other as they pass down the lacteal, ultimately uniting into a single vein, which passes out at the base of the villus.

The Duodenal Glands, or Glands of Brunn, are small racemose (grape-like) glands which are embedded in the sub-mucous areolar tissue. (See Fig. 19.) The largest are about 1 to 1½ lines in diameter; they open into the duodenum by a minute duct.

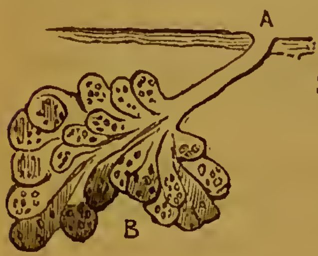


Fig. 19.—Brunner's Gland.

Showing A. Duct opening on the surface of the mucous membrane.

B. Racemose (grape-like) gland.

Their structure very closely resembles that of the elementary lobules of the salivary glands and the pancreas, consisting of clusters of acini, or grape-like vessels, 1-300th of an inch in diameter, lined by tesselated epithelium, and connected together by minute branches of the efferent duct; the whole, in its general arrangement, closely resembling a bunch of grapes. One of these duodenal glands would correspond to an elementary lobule of one of the salivary glands. They are invested by a delicate layer of areolar tissue, and are sometimes described as conglobate glands. (See "Pancreas," and "Salivary Glands.") They secrete a viscid, structureless, alkaline mucus, which is capable of converting starch into sugar.

The duodenal glands are very numerous in the upper

part of the tube, near the pylorus, where they have been described as salivary glands spread out on a large surface instead of being collected into a mass. In the lower part of the tube they are smaller, and are sparsely scattered; they are almost entirely confined to the duodenum and commencement of the jejunum.

The Cæcum (L., *cæcus*, blind), or blind gut, is the large blind or closed sac or pouch which forms the commencement of the large intestine. (See 9, Fig. 14.) It is about $2\frac{1}{2}$ to 3 inches in diameter, and about the same in length. It forms a sort of cul-de-sac, making an acute angle with the ileum, which opens into it. It is situated in the right iliac fossa (cavity), being bound down to the fasciæ of the muscles of the front wall of that region by the peritoneum and areolar tissue; it is comparatively immoveable, and therefore, by its contraction or distention, displaces the neighbouring portions of the small intestine. It is sometimes invested in a complete fold of the peritoneum, termed the meso-cœcum (Gr., *mesos*, middle). Its walls are puckered into small pouches, cells, or sacculi, which are arranged in three vertical rows separated by ridges. This structure is due to the peculiar arrangement of the outer muscular layer, and prevails through the whole of the large intestine, except the rectum.

It has three apertures—a nominal aperture at its commencement, where it joins the colon; a second at its upper, posterior, and left side, which communicates with the ileum; and a third opening which communicates with the vermiform appendix. The cæcum forms the widest portion of the alimentary canal, excepting the stomach. It is in this portion of the intestine that the food begins to acquire the peculiar odour and properties of the fæces.

The Vermiform Appendix (L., *vermis*, a worm) is a small, closed, narrow, worm-shaped tube, two to six inches long, and about the diameter of an ordinary goosequill. It opens into the back of the base of the cæcum, nearly under the ileo-cæcal valve, the orifice being furnished with an imperfect valve or fold. The structure of its walls resembles that of the rest of the large intestines.

The Ileo-cæcal Valve, which guards the entrance of the ileum, and prevents the return or regurgitation of the contents of the colon and cæcum, consists of two valvular folds of mucous membrane.

The Colon (Gr., *koilos*, hollow) is the second and longest portion of the large intestines. (See Fig. 14.) It is connected with the cæcum, commencing at the upper margin of the ileum and terminating at the rectum. It is divided into four portions or segments.

The Rectum (L., *rectus*, straight), or straight gut, commences at the colon, and extends to the anus, or terminal aperture of the alimentary canal. (See Fig. 14.) It is six to eight inches long. Its interior is smooth, cylindrical, and not sacculated, like the rest of the large intestines. It is smaller above, increasing in size down to the anus, immediately above which it is largest, and admits of very great dilatation.

Its lower end is supplied with an internal and an external ring of muscle termed respectively the external and internal sphincter muscles, the relaxation of which opens the anus and discharges the fæces. These muscles are maintained in a state of permanent contraction by the influence of the spinal cord. During panic, paralysis, some forms of insanity, and cerebral disease, this influence is sometimes withheld, producing the involuntary discharge of the fæces.

The lower end of the rectum, which is not invested

by the peritoneum, is partly supported by the levator ani (L., *levo*, I lift up) muscles, which assist in the act of defecation.

The mucous membrane of the rectum is looser than that of the colon, and collects into temporary folds, principally longitudinal. In addition to these, the rectum is supplied with three and sometimes four permanent valves, flaps, or septa, which act like "shelves to pack the fæces on," and prevent the entire weight of the contents of the rectum bearing on the anus.

Peristaltic Movement of the Intestines (Gr., *peri*, about, and *stello*, I send).—The contents of the intestines are gradually urged onwards by the peristaltic action of its muscular walls. This process is compounded of the following movements :—

1. A portion of the circular muscular fibres of the intestines contract, by which a ring or transverse constriction is produced, and its circumference and internal area are greatly diminished ; portions of the intestinal contents are propelled by this contraction into the part of the tube next below it, moving downwards towards the rectum, or termination of the intestines.

2. The portion of the intestinal tube next below the ring or transverse constriction, having received the substance driven from above, now commences the same process of constriction, the first portion of the tube still retaining its contracted state, and propels a portion of its contents into the segment of the intestinal canal next below it.

3. The first segment of the tube now relaxes. Other portions of the tube then take up the action, which thus passes on to the end of the canal by a series of alternate wave-like contractions.

4. According to some writers, the longitudinal muscular fibres aid peristalsis by extending them-

selves behind, so as to slip over the contained substance, and then contracting with it and carrying it forward.

Let A, B, C, and D be four continuous and successive portions of the intestinal canal. On the commencement of the peristalsis, the food, arriving at the portion of the tube represented by A, stimulates its walls to contract upon it, the substance being driven downward into the unconstricted or relaxed part of the tube next below it. This portion of the tube, represented by B, now contracts on its contents, expelling a portion of them. If, while B is contracting, segment A of the tube were to relax, portions of the chyme would be driven backward as well as forward; the segment A, therefore, does not relax until the segment C next below it has become constricted, and propelled a portion of its contents into the part D, when the segment A becomes relaxed. This series of actions is then taken up by segments of the tube next below in succession, until it has passed to the end of the canal. This action is not, however, continuous, but intermittent or rhythmic. According to some writers, this movement is sometimes reversed, the fibres contracting from below upwards in place of their normal succession from above downward; this constitutes anti-peristalsis; its existence is, however, doubted by Dr. Brinton and other modern physiologists of eminence. The ordinary contractions of peristalsis, combined with the obstructive action of any obstacle sufficiently powerful to prevent the onward progress of the food, are quite sufficient to explain the production of a deflected or return current through the central or axial part of the tube. The normal peristalsis of the bowels is much less vigorous than that of the stomach. Dr. Brinton states that a continuous

peristalsis of even two inches per minute would amount "to that of a violent and exhaustive diarrhœa in the human subject."

Probably there are no organs in the body which manifest so strong a tendency to periodicity of action as the intestines; and it is the opinion of many leading physiologists that no function of the body can be so easily regulated as the action of the bowels; yet when this tendency has been long thwarted there are probably few organs of the body whose regular and healthy action it is more difficult to restore. Every person should make it a habit, as a matter of personal duty, to discharge the contents of the bowels once at least in every twenty-four hours. Even when by neglect, or other circumstances, this natural regularity of action has been lost, it may in most instances be re-established by perseverance in the attempt to empty them regularly every day at a fixed hour.

Constipation.—Action of Purgatives (L., *con*, together, and *stipo*, I cram).—When the bowels are sluggish and inactive, they become crowded with fæces, and constipation or costiveness is produced. This state may result from the too feeble peristaltic action of the muscular coats, or the low state of activity of the mucous membrane. In the former case the constipation or costiveness may be temporarily removed by those medicines, as—rhubarb, aloes, colocynth, &c.—which act on the muscular coat, exciting it to increased activity. In the latter case it is more beneficially removed by the action of salines, as Epsom salts, which act upon the mucous membrane, stimulating it to secrete an excess of fluid from the serum of the blood, by which the solid contents of the bowels are dissolved down and washed away. In either case the practice, though it may be attended with temporary benefit to

the system, is decidedly injurious to the organs immediately acted upon. The purgative action of mercurial compounds is partially due to the increased quantity of bile which is poured into the intestine; this increase is consequent on the exalted action of the liver which is excited by these compounds.

Cause of Peristalsis.—The peristaltic contractions are produced partly by the stimulus of the food or solid substances acting directly on the organic muscular fibre, and partly by nervous action through the agency of the spinal cord. They are also probably excited by the distention of the muscular fibres by intestinal gas. Peristaltic movements may be excited by irritation of the solar plexus or the semilunar ganglia, and the sympathetic ganglia of the neck: irritation of the first three cervical spinal nerves, and the cervical portion of the sympathetic nerves, excites peristaltic movements in the œsophagus. Irritation of the roots of the lower cervical spinal nerves of the lowest sympathetic ganglion of the neck, and of the higher sympathetic ganglia (see "Nervous System"), produces contractions in the lower portions of the œsophagus.

The Muscular Coats of the Intestines.—The muscular tunic of the small intestines (see Fig. 15) consists of two layers or planes of unstriped or organic muscular fibre, viz., a thinner external layer of longitudinal, and a thicker internal layer of transverse or circular muscular fibre, in which the fibres are arranged at right angles to the axis of the tube. The muscular coat of the intestines is two to five times thinner than that of the stomach or œsophagus, and its action is therefore much less powerful. The muscular coat of the large intestines also consists of a layer of longitudinal and a layer of circular organic muscular

fibre; but the greater number of the external longitudinal fibres are collected into three flat bands, about one-half of an inch wide, which extend from the base of the cæcum to the rectum. These longitudinal muscular bands are about one-third shorter than the cæcum and colon, to which they are attached, in consequence of which they pucker up this portion of the intestine, producing the sacculi previously described. When they are dissected off the sacculi disappear, the walls of the tube becoming smooth and uniform.

The Mucous Coat of the Intestines consists of the compound variety; its great thickness arises from its involution into tubuli. (See Figs. 15 and 16.) The mucous membrane of the small intestine is villous, that of the large intestines is smooth and destitute of villi. The mucous membrane of both large and small intestines contains tubuli and solitary glands. (See "Structure of Mucous Membrane.")

The Bloodvessels of the Intestines.—The duodenum is supplied with arteries derived from the cœliac axis (Fig. 26). The arteries which supply the lower part of the duodenum, the ileum, the cæcum, and the ascending and transverse colon, are derived from the superior mesenteric artery (Fig. 26) after repeated bifurcations (dividing in twos) and anastomoses. These branches or subdivisions are named according to the parts of the intestines they supply, as the right colic, ileo-colic, &c. The descending colon, sigmoid flexure, and rectum derive their arteries from the inferior mesenteric artery (Fig. 26), which also bifurcates, and anastomoses very freely before giving off the ultimate branches which supply the parts named.

The veins of the intestines correspond with the arteries; the chief veins are the superior and inferior mesenteric. They commence in the arterial capillaries,

and terminate in the portal vein, which distributes the venous blood from the intestines through the liver.

The Nerves of the Intestines are derived from the epigastric or solar plexus of the sympathetic system. The intestines are also probably brought into relation with the spinal nerves and medulla oblongata through the sympathetic system. That the functions of the intestines are performed to a great extent independently of the cerebro-spinal system is shown by the fact that the chief operations of the intestines are not arrested by the section or destruction of the spinal cord.

The Intestinal Juice is described as a viscid, transparent, colourless, structureless, alkaline fluid, generally containing a slight admixture of cell growth. Like the saliva, it acts very powerfully on starch, converting it into sugar.

The Bile is a greenish yellow alkaline fluid, secreted from the portal blood by the liver. It acts chiefly on the fatty portions of the food. This secretion is more fully described under "Organs of Secretion."

The Pancreatic Juice is a clear, colourless, alkaline fluid, secreted by the pancreas. It acts upon the starchy constituents of the food, converting them into sugar; also upon the fats. Its action on the protein compounds is not yet satisfactorily determined. It very much resembles the saliva, and probably promotes the action of endosmose in the intestines by its fluidity. This substance is also more fully described under "Organs of Secretion."

The Chyle (Gr., *chulos*, juice) is the nutritious fluid which is formed in the intestines immediately after the admixture of the bile and pancreatic juice with the chyme, and is absorbed by the lacteals. It varies very much in appearance, according to the time after the last meal, and to the part of the lacteals at which

it is collected. It was once regarded as the very essence of the nutriment. This view, however, is erroneous, as by far the larger part of the nutriment is absorbed into the blood through the veins of the stomach and intestines. When collected from the *receptaculum chyli* a few hours after an ordinary meal, it forms a milky, yellowish white, opaque, or opalescent, feebly alkaline fluid, having a slightly saline, mawkish taste. It is feebly coagulable, and very closely resembles lymph, except in the large quantity of fatty matter it contains, which forms its most distinctive constituent. When collected fasting it is transparent, and can scarcely be distinguished from ordinary lymph. Chyle which has been exposed to the air acquires a reddish colour. When it is collected from the upper part of the thoracic duct it has a pinkish hue, contains a larger number of chyle corpuscles, and a greater quantity of fibrin. When examined under a microscope it is found to consist of a clear transparent fluid, containing chyle corpuscles, about 1-4,600th inch in diameter; oil globules, 1-2,500th to 1-2,000th inch in diameter; and minute molecules of fatty matter which do not coalesce, probably because of an albuminous coating, but are soluble in ether. Mr. Gulliver attributes the milky opacity of the chyle to these particles, which he terms the molecular base of chyle. He describes them as spherical, and having an average diameter of about 1-30,000th of an inch. The milky colour of the serum of healthy blood, which is sometimes observed after a full meal, is due to the presence of this molecular base. When an animal is fed on flesh diet containing no fatty matter the chyle becomes colourless and quite transparent.

Dr. C. Owen Rees gives the following analysis of chyle, taken from the thoracic duct of a criminal, who

had taken, the night previously to his execution, a meal consisting of bread, meat, and tea, and some toast an hour before execution :—

COMPOSITION OF CHYLE.

Water			90·48
Solid residue	Albumen and Fibrin	7·08	
	Water extractive	0·56	
	Osmazome	0·52	
	Salts (similar to those of serum)	0·44	
	Fat	0·92	= 9·52
			100

In this instance the chyle probably contained less than its normal quantity of fatty matter, the man being practically, as far as the chyle was concerned, in a state of fasting, the toast not yet having had time to yield chyle.

The Chyle Corpuscles are minute globular, spheroidal, nucleated cells, comprising, when well developed, a cell wall and contents. (See D, Fig. 22.) Occasionally they present very amœba-like changes of form; their diameter varies from 1-7,000th to 1-2,600th of an inch in diameter.

These corpuscles probably develop into the white or colourless blood corpuscles, the nuclei of which again probably develop into the true red corpuscles of the blood. The number of these corpuscles, and also the quantity of fibrin, greatly increase after the chyle has passed through the mesenteric glands, and during its passage through the thoracic duct, when it becomes more highly organized, assimilating more in its character to that of true blood.

The Fæces (L., *fæx*, dregs), or excrementitious matter expelled from the large intestine, consist of the undigested residue of the food, a portion of the bile, probably including the whole of its colouring

matter, mucus, epithelium scales, and probably a small portion of the disintegrated tissues. The quantity varies from 1-10th to 1-4th of the weight of the solid food. Abrut 2 to 10 oz. are passed daily, containing about 25 per cent. of solid matter, and 75 per cent. of water.

Gases of the Alimentary Canal.—The gases in the stomach and intestines may be produced—1, by the absorption of the oxygen of the air; 2, by the decomposition of the food; 3, by the decomposition of the fluids excreted into the alimentary canal. In some cases of dyspepsia (indigestion), also in some nervous diseases, as hysteria, these gases are developed in excessive quantities. This morbid condition constitutes flatulence. In the disease termed tympanites the abdomen is distended like a drum, the pressure of the gases in some cases impeding the process of breathing, so as to produce death by suffocation. The gases chiefly found in the alimentary canal are nitrogen, carbonic acid, hydrogen, carburetted hydrogen, and traces of sulphuretted hydrogen. The stomach also contains oxygen mixed with a large proportion of nitrogen and carbonic acid.

What becomes of a piece of Bread when eaten? 1. The bread is masticated, by which the cohesion of its particles is partially overcome, and their solution greatly facilitated. 2. It is mixed with saliva, which lubricates it, and facilitates the process of swallowing. 3. It is swallowed (forced down the œsophagus by the action of its muscles). 4. It is mixed with gastric juice in the stomach—the gastric juice dissolves the gluten, the nitrogenous constituent of the bread, forming a solution of peptone, which is partially absorbed by the veins of the stomach—portions of the starch are acted upon by the saliva

and changed into sugar, some of which is also absorbed by the gastric veins; the unabsorbed portions form chyme. 5. The chyme is forced by the vermicular contractions of the stomach into the intestines, where it meets with the bile, and the pancreatic and intestinal juices; the remaining portions of the dissolved peptone are absorbed, and the conversion of starch into sugar by the saliva, now aided by the pancreatic and intestinal juices, is completed, and the dissolved sugar absorbed. 6. The undigested residue, consisting chiefly of cellulose, starch cells, and starch, is passed out of the canal.

Butter.—If butter be eaten with bread, the butter is converted into an emulsion by the action of the bile and pancreatic juice, and absorbed in the form of chyle by the lacteals.

What becomes of a Mutton Chop when eaten?—A mutton chop when eaten undergoes the first three processes, the same as a piece of bread. 4. On arriving in the stomach it is mixed with the gastric juice, which dissolves a portion of the protein compounds, forming them into peptone, which is partially absorbed, and into chyme. 5. The chyme is forced into the duodenum, and mixed with the bile, and the pancreatic and intestinal juices; the remainder of the soluble protein compounds are changed into peptone and absorbed as they are forced through the canal, the pancreatic and intestinal juices aiding this process. The fat is converted into an emulsion and absorbed by the lacteals. 6. The remainder, consisting of the indigestible portions, including the sarcolemma, the cartilage cells, the fibrous portions of the areolar tissue, and of the veins and arteries, are expelled from the intestines. When the quantity of food taken is greater than the wants of the system require, or the

digestive power is impaired, a considerable portion of partially digested food also escapes with the true digestive residuum.

Eggs, raw or boiled, undergo a similar series of changes, the peptone formed from the liquid albumen being chiefly absorbed after its passage into the intestine, and leaving little or no residuum.

ABSORPTION.

THE LYMPHATICS AND LACTEALS.

Absorption.—In addition to the general absorptive power possessed by the veins, to which continual reference has been made in describing the digestive processes, a peculiar absorptive power is exercised by a special system of vessels, termed absorbents or lymphatics, so named because of the lymph they contain. A case of diabetes, illustrating this power, is mentioned, in which the patient must have absorbed 113 pounds of water from the atmosphere in the course of five weeks; other similar cases are on record. An equally interesting case is also described of a jockey, who having reduced himself to the proper weight that he might ride that morning, took one cup of tea only, very shortly after which his weight was found to have increased six pounds, whereby he was prevented from riding. In this case the tea must have stimulated the absorbents into action, causing them to imbibe aqueous vapour from the atmosphere. But whether this absorption was effected by the smaller veins or the lymphatics, or through the lungs or the skin, is uncertain; most probably all these agents participated in the process.

The absorbent system consists of the thoracic duct, right lymphatic duct, receptaculum chyli, lymphatic

and lacteal vessels, and the lymphatic and mesenteric glands. (Fig. 20.)

Distribution and Course of the Lymphatics.—The lymphatics commence in minute tubes a little larger than the capillaries, which ramify and anastomose freely, producing by their repeated junctions larger vessels which follow the general course of the veins, and ultimately discharge their contents into the right and left subclavian veins. The latter vessels pour it into the descending vena cava; from thence it passes into the right side of the heart, which propels it into the lungs, where the useful portions become sanguified, or converted into blood. The distinction made by physiologists between the lacteals and lymphatics is essentially an artificial one.

The lymphatics are distributed all through the body except the brain, spinal cord, and the interior of the eye. They form two sets, the deep and the superficial lymphatics. The lymphatic glands are very numerous in some parts of the body. The principal glands are—the cervical, in the neck; the axillary, in the armpit; the lumbar, in the loins; the inguinal, in the groin; the mesenteric (see Fig. 20), in the folds of the mesentery; and the femoral lymphatics, on the inner side of the thigh.

Structure of the Lymphatics.—The larger lymphatics possess a similar structure to that of the veins, consisting of three coats, viz.—1, an external fibrous coat consisting of compact areolar tissue; 2, a middle elastic coat, of yellow elastic fibre, and of circular unstriped muscular fibres; 3, an inner coat of spindle-shaped epithelial cells supported on a thin network of elastic fibre. They are very abundantly supplied with semilunar valves (similar to those shown in Fig. 28) of fibrous tissue covered with epithelium,

which are placed at very short intervals, their concavities being turned towards the heart, or in the direction in which the current flows. These valves are much more numerous than in the veins. The walls of the lymphatics expand immediately above each valve into a sort of pouch; these expansions give them a very irregular beaded or jointed appearance. Their appearance is best seen when the vessels are distended with lymph. The smaller vessels are composed of a transparent homogeneous membrane, and are destitute of valves; being filled with the transparent lymph, they are in general almost invisible. Some animals, as the frog, are provided with little pulsating sacs or pouches, termed lymphatic hearts, the movements of which help to propel the lymph.

Structure of the Lymphatic Glands.—The lymphatic glands are small, firm, flattened, oval bodies, varying from the size of a hemp-seed to that of an almond, which are situated in the course of the lymphatic and lacteal vessels. They are of a pinkish colour, unless stained by absorbed matter, as in the lungs, where they are rendered black by the carbon; in the liver, where they are stained yellow by the bile; or in the mesentery, where they are white from the chyle.

The Function of the Lymphatics and their Glands is to collect, elaborate, and convey the lymph from the various parts of the body to the subclavian veins, where it is poured into the blood. The lymphatics have been compared to a system of sewerage, draining off the waste fluids from the tissues into the blood, what remains that is useful in the lymph being assimilated, and what is purely excrementitious being removed in the various processes of excretion.

The lymphatics possess a marked power of absorbing

certain injurious, morbid, and poisonous substances, such as the virus of small-pox, vaccine lymph, the poison absorbed through a wound in dissection. In the latter and similar cases the lymphatic vessels of the arm, and the glands in the armpit, become swollen and inflamed, the glands suppurating and becoming ulcerated, apparently in their attempt to arrest the injurious substances and cast them out of the body. Other substances, however, which are refused by the lymphatics, are readily absorbed by the smaller veins of the skin and alimentary canal.

The Lymph (L., *lympha*, water) is a clear, transparent, colourless, or yellowish fluid, containing a number of minute colourless, spherical, nucleated corpuscles, termed lymph corpuscles (see D, Fig. 22), which resemble the white corpuscles of the blood. It is slightly alkaline, and coagulates spontaneously, in consequence of the presence of fibrin. It also, in general, contains, especially after a meal, a greater or less number of minute oil globules. The lymph very closely resembles the chyle of a fasting animal; it is also very similar to the liquor sanguinis, or liquid part of the blood, differing from it chiefly in the larger quantity of water it contains. The following table shows the result of the analysis of lymph obtained from the thigh of a healthy middle-aged woman:—

COMPOSITION OF LYMPH.

Water			93·99
Solids	Fibrin	·056	= 6·01
	Albumen	4·275	
	Fat	·382	
	Extractives	·570	
	Salts	·730	
			100·00

The Lacteals (L., *lac*, milk), or chyliferous vessels, are the lymphatics of the intestines; they derive their peculiar appearance and their name from the milk-like fluid, chyle, they usually contain a few hours after a meal. They originate in the mucous membrane, and especially the villi of the intestines, forming a close network in the submucous areolar tissue. The primitive lacteals in the centres of the villi are 1-1,000th to 1-800th of an inch in diameter. The function of the lacteals is to absorb, elaborate, and convey the chyle from the intestine to the thoracic duct. Their general structure is similar to that of the rest of the lymphatic vessels; they are seen when full of chyle like white threads in the mesentery.

The Mesenteric Glands are the lymphatic glands of the lacteals; they are contained within the layers of the mesentery. (See Fig. 20.) Their number varies from about 100 to 150, and their size from that of a pea to that of a small almond. The number of the corpuscles increases considerably after the chyle has passed through these glands. In scrofulous children these glands swell and become hardened, making the abdomen hard and prominent, and seriously interfering with the nutrition of the child.

The Thoracic Duct is the main trunk of the lacteals and lymphatic vessels. (See Fig. 20.) It commences in the abdomen, about opposite the second lumbar vertebra, and terminates at the left side of the root of the neck; it is about 18 to 20 inches long, and about the diameter of an ordinary goose-quill. It leaves the abdomen by the aortic opening in the diaphragm, ascends to the neck, then curves downwards, terminating in the left subclavian vein at the angle formed by its junction with the jugular vein. Its terminal orifice is furnished with a pair of valves

to prevent the regurgitation of the venous blood into the duct. The thoracic duct commences in an elongated pouch or expansion termed the receptaculum

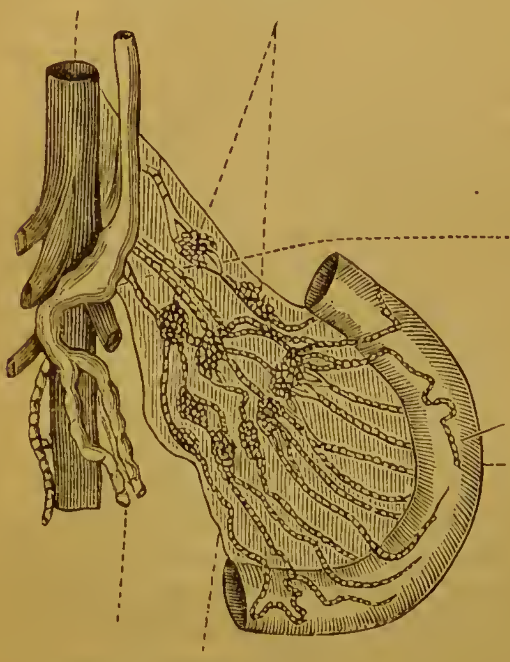


Fig. 20.—THORACIC DUCT AND LACTEALS.
Showing thoracic duct receiving lymphatic and lacteal vessels.

chyli, which receives four to six large trunks (see Fig. 20), formed by the combination of the lymphatics of the lower extremities. It differs but slightly in structure from the larger lymphatic vessels previously described, but is more abundantly supplied with muscular fibre, portions of which in the external coat are collected into isolated fasciculi or bundles. The right

Summary of Digestion and Organs of Digestion.

Processes.

Preliminary processes.
- Prehension.
- Incision.
- Mastication.
- Insalivation.
- Deglutition.

Gastric digestion.
- Secretion of gastric juice.
- Solution of protein compounds and formation of peptone.
- Conversion of starch into sugar.
- Absorption of peptone and sugar.
- Chymification.

Intestinal digestion.
- Chylification.
- Absorption of chyle and fats.
- Absorption of remaining peptone.
- Completion of the metamorphosis of starch into sugar.
- Absorption of remaining sugar.
- Defecation.

Digestive juices.

Solvents.		*lbs.*
Saliva	daily	3 to 4
Gastric juice	,,	13 to 26
Intestinal ,,	,,	½
Bile	,,	3 to 5
Pancreatic juice		½
Mucus	,,	
		20 to 36

Organs.

Preparatory organs.
- Lips.
- Teeth.
- Tongue.
- Cheeks.
- Salivary glands.

Alimentary Canal.
- Mouth.
- Fauces.
- Pharynx.
- Œsophagus.
- Stomach.
- Duodenum.
- Jejunum.
- Ileum.
- Cæcum.
- Apendix vermiformis.
- Colon
  - Ascending.
  - Transverse.
  - Descending.
  - Sigmoid flexure.
- Rectum.

Digestive glands.
- Salivary glands.
- Liver.
- Pancreas.
- Brunner's glands.

Coats of alimentary canal.
- Serous coat.
- Muscular coat.
- Areolar or submucous coat.
- Mucous coat.

Auxiliary structures.
- Valvulæ conniventes.
- Villi.
- Gastric tubuli.
- Intestinal tubuli.
- Peyer's patches.
- Solitary glands.

lymphatic duct conveys lymph from the right side of the head, neck, trunk, and the right arm, to the right subclavian vein.

Movements of the Lymph and Chyle.—The current of the lymph and chyle flows in the direction of the heart. Its velocity, which varies at different periods and in different parts of the body, has not yet been determined with any degree of accuracy.

FOOD—HUNGER AND THIRST.

It has already been shown, in the chapter on Waste, that the animal body is in a state of constant renovation and decay; that every point in its substance is the seat of a perpetual series of births of new particles and deaths of old ones, thus necessitating the continual introduction of new material to occupy the place of the old, worn-out, and effete tissues. The new material ingested into the body to supply the place of the old is termed food.

Two different series of changes of decay are in continual progress, viz.—1. A process of combustion, by which the animal heat is developed and sustained. 2. A process by which the tissues of the various organs are disintegrated in the performance of their respective functions. Two kinds of food are therefore rendered necessary, viz.—1. Heat-forming, respiratory, or fuel food, to supply the animal heat. 2. Flesh or tissue-forming food, to supply the elements of growth, repair, and renovation.

Functions of Plants in Relation to Animal Life.—The animal body has very little chemical constructive or synthetic power; it cannot therefore subsist on mineral or inorganic matter. It has no power to construct the proximate principles of which its tissues are built up; it must therefore be supplied with these

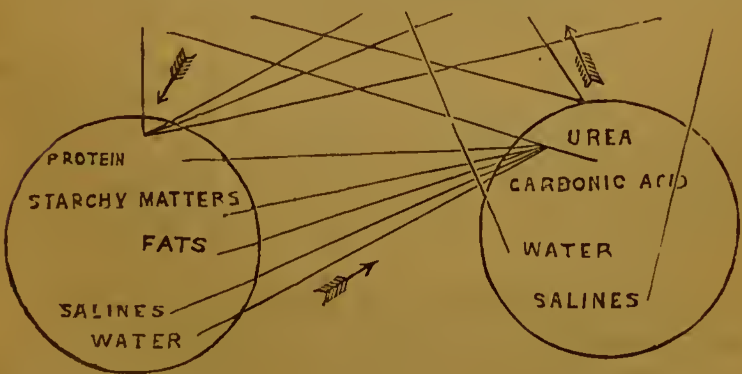
principles ready made, or it cannot exist. This is the grand function of plants. Plants possess the constructive power in which the animal is deficient; they build up and supply its proximate principles; they alone render animal existence possible, and thus form the intermediate link connecting animal life with inanimate nature.

An animal cannot live on air, water, sand, or other mineral substance; a plant not only subsists on these substances, but elaborates from them into its own tissues the very elements necessary to the development, growth, and sustenance of the animal.

The vegetable world is therefore, as it were, an immense natural manufactory of the raw material of the animal structure. The plant itself is worked up from still simpler materials, viz., carbonic acid, water, ammonia, and certain salts. The following diagram from Prof. Huxley's "Lectures on Organic Nature" shows this relation very clearly:—

Inorganic World.

Carbonic acid. Water. Ammonia. Salines.



Vegetable World. Fig. 21. Animal World.

The plant gathers and absorbs carbonic acid, water, and ammonia from the atmosphere, and minute quan-

tities of earthy salts from the soil. It decomposes the carbonic acid, evolving its oxygen, which again restores purity to the atmosphere. A portion of the absorbed carbon, hydrogen, and oxygen it converts into woody fibre, sugar, and starch, while out of other portions of these elements, together with nitrogen, it elaborates the higher and more complex protein compounds indispensable for the development and sustenance of animal life. The animal eats the plant, assimilates its protein compounds, which it elaborates into its own tissues; appropriates the starch and the sugar as fuel to sustain the combustion necessary for the development of its internal heat; inhales oxygen, which at the same time develops life, but destroys the organism, oxidizing and burning the starch and sugar, by which they are again resolved into carbonic acid and water; and oxidizes and degrades the assimilated protein into urea, which is expelled from the organism, and resolved into carbonic acid and ammonia, which are destined ultimately to re-enter the same cycle of change. The following table by Dr. Carpenter indicates synoptically the part played by animals in the conversion of food:—

Food, consisting of albuminous and other compounds,	converted into	Living organized tissue,	and this metamorphosed into	Carbonic acid and water thrown off by respiration.
				Urea and biliary matter. thrown off by other excretions.

These changes are incessant during the life of the animal; but ultimately it dies, and is entirely resolved into its inorganic elements. And there can be no doubt that the material elements which formerly entered into the composition of and helped to build up the bodies of the ancient races who have long

since been gathered to their fathers, now perform similar offices in the bodies of living men.

The following table shows the leading distinctions between plants and animals in relation to food and digestion :—

Animals	Vegetables
Live on highly azotized organic food.	Appropriate but small quantity of azotized inorganic food.
Live actively.	Live slowly.
Waste rapidly.	Waste slowly.
Renovate and repair slowly.	Change slowly.
Consume proximate principles.	Live on inorganic food.
Convert one proximate principle into another.	Build up proximate principles.
No animal is nourished by carbonic acid or ammonia.	Plants nourished by carbonic acid and ammonia.
Changes produced by inherent powers of organism.	Changes produced by external forces, heat, light, and electricity.

Quantity and Kind of Food dependent on Waste.—Food is rendered necessary by bodily waste; the quantity of food required must therefore depend on the rate of the waste, and the quality or kind of food upon the nature of the waste. The principal waste of the body consists of carbonic acid and water evolved from the lungs, and urea and uric acid excreted by the kidneys and the organs connected with the alimentary canal. The daily supply of food must therefore contain as much carbon, hydrogen, and nitrogen as is daily excreted from the body in the former substances, or the body must fall into ruin. But the animal organism possesses only a very feeble constructive power; the nitrogen required must be therefore presented to it very nearly in that form in which it is assimilated by the body; in other words, the nitrogen must be presented in the form of "pro-

tein," or some modification of it, as albumen, fibrin, and casein, more or less similar to that which exists in the tissues. The composition of the body remaining the same, the quantity of the nitrogenous or proteinous food daily required to build up the wasted tissues must be such as shall contain an amount of nitrogen equal to that contained in the urea and other nitrogenous excretions.

By determining the daily amount of these excretions or degraded tissues, the quantity of flesh-forming or nitrogenous food which must be ingested per day, to sustain the animal body at its full weight and vigour, may be calculated with a fair degree of accuracy.

In like manner, the quantity of carbon that must be taken into the body daily in the carbonaceous or heat-forming food, must equal the quantity of carbon evolved from the lungs and the skin in the form of carbonic acid, *plus* the carbon passed out of the system through the bowels and the kidneys.

If the whole of the food taken were digested, it would be easy to determine the amount of the excretions proper, and thus the quantity of the tissues disintegrated daily; but in general considerable quantities of undigested food pass out of the intestines with the excretions, and there is no certain mode of accurately determining the respective quantities of these egesta.

Nitrogenous Food an Exponent of Work.—It is a familiar fact that for a man or a horse to work hard he must eat well; but science alone can indicate the mathematical accuracy of the relation between eating and working. Dr. Playfair, in a most interesting, instructive, and philosophical paper recently published, entitled "The Food of Man in Relation to

his Useful Work," has produced much additional evidence, showing that the nitrogenous food alone becomes a source of dynamical or mechanical and of mental work. He shows that a horse may be kept in a condition of health during a state of quietude when fed on 12 lbs. of hay and 5 lbs. of oats,—food containing about 29·2 oz. of nitrogenous or flesh-forming food; but that if required to do much work, he should get 14 lbs. of hay, 12 lbs. of oats, and 2 lbs. of beans, which contain about 56·2 oz. of flesh-formers. The difference in these amounts therefore indicates the amount of the flesh-formers required for the performance of the mechanical labour, over that required for mere subsistence, as follows:—

Horse at work . .	56·2 oz. of plastic food.	
Horse at rest . .	29·2	,,
Difference .	27·0 oz.	,,

The food equivalent of the mechanical labour of the horse is therefore 27 oz. of flesh-formers.

Again, the amount of flesh-forming food required to keep an ordinary man of good health in a state of quietude is about 2 oz.; and the amount of flesh-formers required to keep the same man in a state of health when performing similar mechanical labour (pulling weights horizontally) is 5·5 oz.

Man at work	requires	5·5 oz. of flesh-formers.	
Man at rest	,,	2·0	,,
Difference for work		3·5 oz.	,,

The horse at work therefore consumes $\frac{27}{3\cdot5} = 7\cdot7$, or nearly eight times as much labour-food as the man at work. But what relation does the quantity of work

performed by the man bear to the quantity of work performed by the horse? Mechanical physicists have estimated the work of a horse at 12,400,000 foot pounds, and the work of a man at 1,500,000 foot pounds; therefore

$$\left\{\begin{array}{l}\text{the work of horse} = \\ \quad\text{,,} \qquad \text{man} = \end{array}\right. \frac{12,400,000}{1,500,000} = 8;$$

or, in other words, the work of the horse bears the same relation to the work of a man that the labour-food of the horse bears to the labour-food of the man.

Let this same inquiry be extended to the labour of the ox. Dr. Playfair states that a well-fed ox gets 50 lbs. mangel-wurzel, 3 lbs. of beans, and 17 lbs. of wheaten straw per day, the whole containing 38·6 oz. of flesh-formers. The work of an ox has been estimated at 8,640,000 foot pounds.

$$\begin{array}{l}\text{Work of horse in foot pounds} = \\ \quad\text{,,} \quad \text{ox} \qquad\quad \text{,,} \qquad = \end{array} \frac{12,400,000}{8,640,000} = 1·43;$$

that is, the work of the horse is 1·43 times that of the ox.

But the labour-food of the horse, divided by the labour-food of the ox, $= \frac{56·5}{38·6} = 1·46.$

That is, the labour-food of the horse is about as many times greater than the labour-food of the ox as his work is greater than the work of the ox.

It is said that railway contractors practically recognise the principle of "food an exponent of work" by discharging those labourers whose appetites fail.

Food required per Day.—The quantity of food required per day to sustain the body of an adult in a state of health is a problem which has recently undergone considerable patient investigation. It varies greatly with age, temperature, and work. There are

two modes of determining this problem with various degrees of accuracy. The first consists in ascertaining by careful examination and inquiry the amount of food actually consumed by different bodies of men of all classes of the community under the different circumstances of labour, quietude, &c.; the second consists in determining accurately the amount of the various excretions, particularly carbonic acid and urea. The former is probably much the safer for practical guidance, the latter probably much more accurate for scientific purposes. For detailed information on the subject of diet the reader is referred to the able, simply written, and eminently practical treatise of Dr. E. Smith, entitled "Practical Dietary," which should be in the possession of every family man, schoolmaster, employer, and social reformer.

The following table shows some of the results of Dr. Smith's inquiries with regard to the carbon excreted by adults of various occupations, also the carbon ingested in the food eaten by the same classes. It refers to men in the middle life and of full average health, size, and activity.

Carbon Excreted per Day.		Carbon Consumed per Day.	
In perfect quietude . .	7·9	Cotton and silk operatives, stocking weavers, needlewomen, shoemakers . . .	10·5
Middle and light labouring classes . . .	9·5	Outdoor labouring classes	13·2
Hard labouring classes .	12·5		

Dr. E. Smith infers that the adult body occupied in middle or light labour requires a daily minimum supply of food containing 9½ to 10 oz. of carbon; and that the ordinarily hard working classes require a minimum supply of carbonaceous food containing 12½ to 14 oz. of carbon. He estimates the quantity of carbon actually consumed per day at 25 grs. for every 1 lb.

of the bodily weight. In addition to this, a portion of carbon from the food escapes by the bowel, making a total of 28 grs. of carbon actually required as a minimum to sustain the body of an adult weighing 150 lbs. in a state of permanent health.

Dr. Smith, estimates that in the case of an infant 136 grs. of carbon was given daily for each 1 lb. of its weight, the infant thus receiving three or four times as much carbon in proportion to its weight as is ordinarily supplied to an adult.

Dr. Smith, pursuing a similarly extensive course of investigations with respect to the quantities of nitrogen excreted daily, arrived at the following results:—

Nitrogen Excreted Daily.		Nitrogen Consumed in Daily Food.	
Middle and light labouring classes	about 200 grs.	Light labouring indoor classes	183 grs.
Middle and well-fed classes .	,, 260 ,,	Outdoor labourers in England	242 ,,

There is a slight discrepancy in the above quantities between the amount of nitrogen consumed and excreted, the latter being in excess, which he does not explain.

Dr. Smith infers from these data that a lightly occupied adult requires 200 grs., and an ordinarily hard-working labourer 250 grs. of nitrogen per day in his food.

The nitrogen actually assimilated or taken into the blood was 0·934 gr. to 1·4 gr. for each 1 lb. weight of the body. Adding to this the amount daily passed off in the refuse food, he estimates the total amount of nitrogen required in the food per day at 1 to 1½ grs. for each 1 lb. of the weight of the body.

The nitrogen required by the infant for each 1 lb.

body weight is about six times that required by the adult.

The reader will bear in mind the distinction between the nitrogen and the nitrogenous substance consumed, the latter being many times greater than the former.

Dr. Brinton gives the loss of albuminous or nitrogenous substances at $1\frac{2}{3}$ oz. per day, or about 1-1,350th of the entire weight of the body, which must be restored by food. He also states that a new-born infant weighing 6 to 7 lbs., taking 10 to 12 oz. of milk per day, introduces about 1-270th of its total bodily mass daily.

The following table shows the quantity of salts required to supply the daily loss of these substances :—

QUANTITY OF SALINE CONSTITUENTS REQUIRED DAILY.

Phosphoric acid	32	to	79	grs.
Chlorine	51	,,	175	,,
Sulphuric acid	17	,,	41	,,
Potash	27	,,	107	,,
Soda	80	,,	171	,,
Lime	$2\frac{1}{3}$	,,	$6\frac{1}{3}$	,,
	$209\frac{1}{3}$	to	$579\frac{1}{3}$	grs.

If the chlorine and sodium be reckoned together as common salt, about 200 grs., or nearly half an ounce, is required daily. But it must be recollected that the greater portion of this substance is already contained in the food, without any further addition of the mineral itself.

Water can scarcely, in the accepted sense of the term, be considered food, since in all probability the water entering into the chemical composition of the tissues is derived from the water chemically combined with the food, yet it is an indispensable accompaniment of most ordinary kinds of food. The quantity retained in the body varies with exercise, temperature, &c. It is retained in the body in much larger quantities dur-

ing rest than during activity; and the great reduction in the bulk of the body which occurs during a course of training for a pedestrian race, or a pugilistic contest, is due to the loss of this fluid. Water is the essential vehicle by which the food is conveyed into the system, and by which the waste materials are removed out of it. The quantity of water required to supply the daily wants of the system, under conditions of moderate exertion and temperature, is estimated at about 6 lbs., or nearly 5 pints.

	Sub-sistence Diet.	Diet in Quietude.	Diet of Adult in Full Health.	Diet of Active Labourers.	Diet of Hard-worked Labourers.
	oz.	oz.	oz.	oz.	oz.
Flesh-formers	2·0	2·5	4·2	5·5	6·5
Fat . .	0·5	1·0	1·8	2·5	2·5
Starch . .	12·0	12·0	18·7	20·0	20·0
Starch equivt.	13·2	14·4	22·0	26·0	26·0
Carbon .	6·7	7·4	11·9	13·7	14·3

A prize-fighter in training, who walked 17 miles daily for exercise, consumed the following:—

Flesh-formers	9·8	oz.
Fat	3·1	,,
Starch	3·27	,,
Starch equivalent	10·70	,,

Definition of Food.—Food may be defined, with sufficient accuracy for all practical or scientific objects, as consisting of all those nutritious substances which are taken into the alimentary canal from the exterior of the body for the purpose of being digested.

Classification of Food.—Food is classified, according to its nature and functions, under three divi-

sions, viz. :—1. Plastic or nitrogenous food, which builds up, repairs, and nourishes the tissues. 2. Respiratory or fuel food, which sustains the animal heat. 3. Mineral food, consisting of minute quantities of the alkaline and earthy salts.

The following table shows the different kinds of food and their principal varieties :—

Food.	Inorganic	Water.			
		Salts.			
	Organic .	**Plastic** .	Albumen .		Contains oxygen, hydrogen, carbon, and nitrogen.
			Fibrin .		
			Casein .		
			Gelatin (?) .		
			Gluten .		
			Legumin .		
		Respiratory .	Oleaginous	Fats	Contains carbon, hydrogen, oxygen.
				Oils	
			Saccharine .		
			Starchy .		

Plastic Food (Gr., *plasso*, I form), so called because it affords the material out of which all the tissues are originally formed, and by which they are subsequently repaired and nourished. It is also termed flesh-forming, azotized, nitrogenous, or albuminous food. This kind of food has been described as exclusively consisting of true nutriment, but there can be but little doubt that some of the elements of the tissues are also derived from the carbonaceous or heat-forming food.

All vegetables contain more or less of these flesh-forming principles; a few of them, as peas and beans, contain them in very great abundance, but in a form comparatively indigestible to human beings. The principal plastic constituents of flesh meat are albumen, fibrin, and gelatin (it is doubtful whether the latter exists in uncooked meat; its nutritive value is also doubtful); of bread, gluten; of peas and beans, legu-

min. Milk is generally regarded as a model food, containing all the various constituents of the food necessary to perfect nutrition, viz., the plastic, the oleaginous, the saccharine, and the saline principles. The plastic element in milk is casein; the respiratory elements consist of fat (butter) and sugar of milk. It also contains phosphate of lime and other salts necessary to the formation of bone and other tissues.

The following tables by Dr. Brinton show the composition of human and cows' milk:—

HUMAN MILK.

Water					88
Solids	Flesh-formers, Casein		3·5		12
	Heat-givers	5·0 Sugar 3·3 Butter	8·3		
	Salts		·2		
					100

COWS' MILK.

Water				86	
Solids	Flesh-formers, Casein		5·5	14·2	
	Heat-givers	3·5 Sugar 4·5 Butter	8·0		
	Salts		·7		
				100·2	

It will be seen from the above tables that cows' milk contains less water and sugar of milk, but more butter: to make it approximate in composition to that of human milk, for use in the nursery, it therefore requires to be diluted with water, and sweetened by the addition of sugar of milk.

COMPOSITION OF FLESH MEAT (BEEF).

Water				50
Flesh-formers	Fibrin and Albumen 8 Gelatin (?) 7	15	Solids	50
Heat-givers	Fat	30		
Mineral matter	(Salts)	5		
				100

One-half of ordinary uncooked beef, as is seen from the table, consists of water; consequently several vegetable substances, as lentils, peas, and beans, which contain comparatively little water, are, bulk for bulk, or weight for weight, much richer in plastic food. But little importance can be attached to the quantity of gelatin mentioned in the table. It is doubtful whether it exists in raw meat, or in flesh in its natural state, and its properties as a flesh-former are still more open to suspicion. The great value of flesh meat results not so much from its richness in the nitrogenous or plastic elements as from their easy digestibility.

The following tables show the proximate chemical composition of ordinary wheaten flour, barley, oatmeal, potatoes, rye, rice, peas, and lentils :—

WHEATEN FLOUR.

Water			14·0
Flesh-formers	Gluten	12·8	14·6
	Albumen	1·8	
Heat-givers	Starch	59·7	68·1
	Sugar	5·5	
	Gum	1·7	
	Fat	1·2	
Cellulose (fibre)			1·7
Ashes			1·6
			100·0

BARLEY.

Water			14·0
Flesh-former	(Gluten)		12·8
Heat-givers	Starch	48·0	55·8
	Sugar	3·8	
	Gum	3·7	
	Fat	0·3	
Woody fibre			13·2
Ashes (mineral matter)			4·2
			100·0

OATMEAL.

Water			13·6
Flesh-formers			17·0
Heat-givers	Starch	39·7	53·8
	Sugar	5·4	
	Gum	3·0	
	Fat	5·7	
Fibre			12·6
Mineral matter			3·0
			100·0

POTATO.

Water			75·2
Flesh-formers			1·4
Heat-givers	Starch	15·5	19·3
	Sugar	3·2	
	Dextrine	0·4	
	Fat	0·2	
Fibre			3·2
Ashes			0·9
			100·0

The potato is the least nutritious (flesh-forming) plant cultivated for human food. 1 lb. of potatoes only contains 1-3rd of an oz. of flesh-formers. In Ireland a labourer is allowed 10½ lbs. daily, in addition to a large supply of buttermilk.

RYE.

Water			13·00
Flesh-formers	Gluten	10·79	13·83
	Albumen	3·04	
Heat-givers	Starch	51·14	61·14
	Gum (?)	5·31	
	Sugar	3·74	
	Fat	0·95	
Woody fibre			10·29
Mineral matter			1·74
			100·00

RICE.

Water			13·5
Flesh-former (Gluten)			6·5
Heat-givers	Starch	74·1	76·2
	Sugar	0·4	
	Gum	1·0	
	Fat	0·7	
Woody fibre			3·3
Mineral matter			0·5
			100·0

PEAS.

Water			14·1
Flesh-former (Casein or Cheese)			23·4
Heat-givers	Starch	37·0	50·0
	Sugar	2·0	
	Gum	9·0	
	Fat	2·0	
Woody fibre			10·0
Mineral matter			2·5
			100·0

LENTILS.

Water			14·0
Flesh-former (Casein)			26·0
Heat-givers	Starch	35·0	46·0
	Sugar	2·0	
	Gum	7·0	
	Fat	2·0	
Woody fibre			12·5
Mineral matter			1·5
			100·0

Peas, beans, lentils, and other leguminous plants are among the most highly nutritious substances known; but they, especially the two former, are exceedingly indigestible. The meal of the lentil enters largely into

the food much advertised under the name of Revalenta Arabica. It is said the red pottage which tempted Esau to sell his birthright was made of lentils.

Gluten (L., glue), or vegetable fibrin, is the nitrogenous constituent of cereal seeds. It forms the grey, sticky, tenacious, tasteless substance which is left when flour is made into a paste, and kneaded in a fine linen bag, under a gentle stream of water, so long as the water is rendered milky. It very much resembles birdlime. The white substance washed away consists of starch.

Legumin is the nitrogenous principle of beans, peas, and lentils; if not actually identical with casein, or cheese, it very closely resembles it. The Chinese prepare a kind of cheese from peas.

Heat-forming, respiratory, carbonaceous, or fuel-food abounds in carbon and hydrogen, the combustion of which in the body develops and sustains the animal heat. The chief respiratory foods are starch, sugar, and the fats. In the two former the carbon only is burnt, the hydrogen being already oxidized; in the latter the hydrogen as well as the carbon is burnt; it is therefore a more powerful respiratory food than the former. Starch and sugar contain oxygen in the proportions in which they form water; that is, the number of atoms of oxygen and hydrogen they contain are equal. Fats contain a very large excess of hydrogen, and but a small proportion of oxygen; the heat developed by the combustion of equal weights of sugar and fat is therefore much greater in the case of the latter than of the former.

In very cold regions the quantity of fat consumed would scarcely be credited but for the known veracity of the authorities by whom the facts are reported. Sir John Franklin states that he tried how much fat an

Esquimaux lad about 14 years of age could eat. The boy devoured 14 lbs. of tallow candles and a piece of fat pork, and would have consumed more, but Sir John felt he had already sacrificed enough for the purpose of an experiment.

Butter possesses the general food properties of other oils and fats; in addition to which it has the property of being exceedingly palatable, which accounts for its extensive use. Though the fats are essentially heat-forming, there can be but little doubt that they aid nutrition by combining with the albuminous principles of the blood (especially when, as in that fatal disease, consumption, they are in excess), thereby rendering the blood more plastic (increasing its tissue-forming power), and preventing the formation of tubercle. The powerful preventive and curative agency of cod liver oil in consumption is attributed to this action. Every child should be trained to eat fat at its meals, but treacle, which is often used in the poorer families in place of butter, is, especially during the colder months of winter, a very inferior food substitute for it.

Stimulants are defined as substances which temporarily increase the activity or force of the system, or of a part of the system; the temporary excitement being followed by a recoil or depression of greater or less intensity, bearing proportion to the previous excitement. Dr. Anstie, in an able work recently published, shows this definition to be open to serious objection; but the limits of this little book will not allow of further reference to this interesting subject. The principal stimulants in ordinary use are tea, coffee, beer, wine, and spirits.

The following tables show the composition of tea and coffee:—

TEA.

Water			5·00
Flesh-formers	Theine	3·00	18·00
	Casein	15·00	
Heat-formers	Aromatic oil	0·75	25·75
	Sugar	3·00	
	Gum	18·00	
	Fat	4·00	
Tannic acid			26·25
Woody fibre			20·00
Mineral matter			5·00
			100·00

COFFEE.

Water			12·000
Flesh-formers	Caffeine	1·750	14·750
	Casein	13·000	
Heat-formers	Aromatic oil	·002	27·502
	Sugar	6·500	
	Gum	9·000	
	Fat	12·000	
Potash with peculiar acid			4·000
Woody fibre			35·048
Mineral matter			6·700
			100·000

Though it is usual to describe the constituents of tea and coffee as flesh-formers and heat-formers, it is tolerably certain that they are not digested, and therefore have no such value. The use of these substances really depends upon the palatable beverage and the refreshing stimulus they afford, and not upon their food-power. Their stimulating properties are chiefly due to the theine or caffeine and the volatile oil they contain.

Cocoa, which is frequently substituted for tea and coffee, however, differs greatly from them in affording an exceedingly nutritious liquid food in place of mere

stimulating drinks. Its proximate chemical composition differs from that of tea and coffee principally in the large quantity of fat and albumen it contains. Theobromine is very similar to theine or caffeine in its chemical qualities and composition.

COCOA.

Water			5·0
Flesh-formers	Albumen	20·0	22·0
	Theobromine	2·0	
Heat-formers	Butter	50·0	63·0
	Gum	6·0	
	Starch	7·0	
Woody fibre			4·0
Red colouring matter			2·0
Mineral matter			4·0
			100·0

The Alcoholic Stimulants, beer, wine, and spirits, are neither useful nor economical as food; they depend for their popular use on their stimulating properties, which are due to the alcohol they contain, and which vary in degree according to the quantity of alcohol present. Alcohol contains no nitrogen, and therefore contains no flesh-forming principle, and can add nothing to the substance of the decaying tissues. It was formerly classed among the heat-forming foods, and supposed to save the tissues by supplying the combustion material necessary to the development of the animal heat; but it was classed among these bodies from purely theoretical considerations. Recent experiments tend to show that alcohol undergoes no chemical change in the body, that it does not become oxidized in the system, but passes out unburnt as alcohol, and therefore can neither have developed heat nor have saved the tissues. Alcohol is also said by some writers to economize the tissues by arresting waste;

but the experiments of Dr. E. Smith show that certain kinds of spirit actually increase the waste of the system. The testimony of all the great authorities who have latterly had the opportunity of observing its effects on masses of men exposed to excessive cold or heat, or on those who are required to exert great and continuous mental or muscular labour, is decidedly against the use of these stimulants.

Beers consist of the partially fermented infusions of certain plants; they contain water, alcohol, acetic acid, sugar, starch, gum, traces of gluten, and minute quantities of certain bitter principles derived from the hop. Weak beer contains 1 to 3 per cent. of alcohol, strong beer and stout 4 to 6 per cent., strong ales 8 to 10 per cent., and very old ales that have been kept many years 10 to 25 per cent.

Wines consist of the fermented juice of certain fruit containing sugar (glucose); they contain water, alcohol, sugar, tartaric acid, minute quantities of potash, and certain aromas. The inferior wines contain 5 to 6 per cent. of alcohol, fair light wines 10 to 15 per cent., and strong wines, as port or sherry, 15 to 25 per cent., and upwards.

Ardent Spirits are obtained by the distillation of wines or other fermented liquors; their distinctive flavours are due to certain essential oils, which are either added or developed during the process. They consist of water, alcohol, and traces of certain essential oils. Brandy, gin, and whiskey, contain 40 to 50 per cent. of alcohol.

Condiments are substances taken with the food to impart relish, or stimulate the digestive organs. The chief condiments used in this country are salt, mustard, pepper, and ginger. They stimulate the action of the salivary glands and the mucous coat of

the alimentary canal. With the exception of salt, the less these condiments are used in health the better, especially by the young. Their free use produces artificial thirst, and thus sometimes leads to the formation of drinking habits.

The following table, which is founded upon the results of Dr. Beaumont's experiments, is extracted from Combe's "Physiology of Digestion:"—

TABLE SHOWING THE DIGESTIBILITY OF DIFFERENT KINDS OF FOOD.

	h.	m.
Rice, boiled	1	0
Tripe ,,	1	0
Eggs, raw	1	30
Apples, ripe, raw	1	30
Brains, boiled	1	45
Sago ,,	1	45
Tapioca ,,	2	0
Milk ,,	2	0
Milk, raw	2	15
Eggs, roasted	2	15
Gelatin, boiled	2	30
Potatoes, baked	2	30
Mustard, baked	2	45
Apples, sour, raw	2	50
Oysters, raw	2	55
Eggs, soft-boiled	3	0
Beefsteak, broiled	3	0
Mutton, boiled	3	0
Apple dumpling, boiled	3	0
Bread, wheaten	3	30
Butter, melted	3	30
Cheese, old and strong	3	30
Potatoes, boiled	3	30
Eggs, hard-boiled	3	30
Heart, fried	4	0
Fowl, boiled	4	0
Veal, broiled	4	0
Beef, hard, old, salted, boiled	4	15
Soup, beef, vegetables, and bread	4	0
Soup, marrow-bones	4	15
Pork, salt, boiled	4	30
Veal, fried	4	30
Duck, roasted	4	30
Suet, beef, roasted	5	3
Pork, roasted	5	15

Nutritiousness and **Digestibility**, though generally confounded in the popular estimation, are entirely different properties. Some bodies, as cheese, consist almost entirely of nutriment, but are exceedingly indigestible; others again, as rice, are exceedingly digestible, but contain comparatively little nutriment.

Economical Admixture of Foods.—About 300 grains of nitrogen and 4,600 grains of carbon are daily thrown out of the system by the lungs, skin,

kidneys, and bowels. A well-arranged system of diet should supply these elements in very nearly their due proportion, and not compel us to take very much more of the one element in order that we may obtain the requisite supply of the other. Hence arises the economy of the proper admixture of foods. If a man lived on potatoes alone he would require at least 13 lbs. daily to supply the required nitrogen; if on bread, he would require 4 lbs.; while, on the other hand, if he lived on meat alone, he would require 6½ lbs. daily to supply the necessary carbon; whereas an admixture of 2 lbs. of bread and ¾ lb. of meat would be amply sufficient, thus economizing both food and digestive power.

Cooking renders the food more digestible, savoury, and palatable. It promotes its digestion principally by gelatinizing and rendering soluble the sarcolemma which surrounds the muscular fibre of the flesh and the cell walls which enclose the fat, and thus exposing their contents to the action of the digestive juices. This not merely lessens the labour of the digestive organs, but reduces the quantity of food actually required by lessening the amount that passes through the bowels undigested.

Hunger.—The peculiar sensations consequent on hunger would seem to refer it to the stomach; also the fact that in the normal condition of the body the feeling disappears on the introduction of food, or even indigestible and innutritious substances. It is well known that some savage and half-civilized races are in the habit of introducing clay, sawdust, and other similar innutritious substances into the stomach to allay the cravings of hunger. Its pangs are thus probably somewhat allayed, but the sense of emptiness and the faintness arising from want of food remain.

Hunger has been variously attributed by different physiologists to the following causes :—

(1.) Emptiness of the stomach.

(2.) The irritation of the coats of the stomach by the gastric juice.

(3.) To the distention of the stomach follicles by the gastric juice.

(4.) The wants of the system.

(5.) The capillary condition of the coats of the stomach.

(6.) The subjective feeling consequent on the state of the brain and nervous system. Dr. Mayo states that a person may be hungry without a stomach and thirsty without a throat.

Thirst—Seat of Thirst.—Thirst, like hunger, is a general or systemic sensation; that is, a state of feeling brought about by the wants of the system. Its more immediate or local seat is the mucous membrane of the back of the mouth, the fauces, and the top of the throat. Its normal cause is a deficiency of fluid in the body; and it may be immediately relieved by introducing water into the system through an opening in the stomach, through the intestines, through the skin, or by immersion in a warm bath.

Summary of Food—Hunger and Thirst.

Food consists of substances taken into the stomach for the purpose of digestion, or conversion into blood. Food is rendered necessary by the waste of the system. Food is the primary source of nervous and muscular power. Food which supplies calorific power is termed heat-forming, respiratory, carbonaceous, or fuel food; and consists of starchy, saccharine, or oleaginous bodies which contain a preponderance of carbon, or

carbon and hydrogen. Food which supplies dynamical (mechanical and mental) power is termed histogenetic (tissue-forming), nitrogenous, azotized, proteinous, or albuminous; and consists of substances which are comparatively rich in nitrogen, as milk, eggs, flesh, cheese, peas, beans, and other bodies containing fibrin, albumen, casein, or gluten.

A small portion of the respiratory food also probably contributes to the formation of the tissues; and likewise a portion of histogenetic or albuminous food to the development of the animal heat.

The student and the hard-labouring professional man require even more histogenetic or tissue-forming food than the ordinary physical labourer.

A due supply of animal food is necessary to the development of a high civilization; that is, to the development of races who are capable of sustained muscular and mental labour.

Alcohol, either strong or dilute, cannot possess any histogenetic power from its deficiency of nitrogen; and, as far as the results of modern experiments can show, is neither oxidized nor burnt in the system, and therefore is probably neither a heat-former nor a flesh-former. It is consequently deficient in true food-power, or, in other words, can neither nourish the body nor develop heat.

A due mixture of heat-forming and flesh-forming food is most beneficial, economizing both food and digestive (vital or nervous) power.

An excess of animal food is much more injurious than a corresponding excess of vegetable food.

Cooking renders food more savoury, wholesome, and digestible, and destroys the parasitic animals which might otherwise excite serious if not fatal disease; saves food, and enables the same amount of digestive (vital) power to do more effective work.

Hunger and thirst are peculiar sensations respectively due to the general wants of the system. The former manifests itself locally in the stomach, and arises from a deficiency of nutriment; while the latter manifests itself locally in the region of the fauces, and is consequent on a deficiency of fluid in the system.

THE BLOOD.

Blood.—The blood is the nutritive fluid contained in the veins and arteries, out of which the various tissues are built up, repaired, and renovated, and by which the various organs receive the vital stimulus which enables them to perform their respective functions. It is popularly described as a bright scarlet fluid; but this is only partially true, one-half of the blood in the body being of a dark purplish colour. This mistake has arisen from the fact that the dark purple blood, which cannot be seen in the body, immediately changes from its dark purple hue to a bright scarlet colour when it escapes from the veins and comes into contact with the oxygen of the air. The blood has been beautifully described as the "river of life." Its excessive loss produces death by syncope, or fainting. After the blood has been drawn from the body it coagulates—that is, spontaneously separates into a clear liquid and a red gelatinous mass. It is slightly viscid, has a saltish taste, and a peculiar faint odour resembling that of the perspiration. This odour is said to be rendered more intense by the addition of sulphuric acid. To the naked eye blood is apparently homogeneous. Arterial blood is of a bright red colour. Venous blood is of a dark or purplish red by reflected light, but when a thin layer is held up and viewed by transmitted light it appears of a greenish colour; it is therefore said to be dichromatic.

The Quantity of Blood contained in the body of an adult man is not known with any degree of accuracy, though many attempts to determine it have been made by the ablest physiologists. It has been varoiusly estimated at from 12 to 28 lbs.

Structural Character of the Blood.—Human blood, when viewed by the naked eye, appears to be a simple and perfectly homogeneous red fluid; but when observed with a high magnifying power it loses this homogeneity of appearance, and is seen to consist of myriads of distinct microscopic structures, the red and white corpuscles floating in a clear transparent fluid, termed the serum.

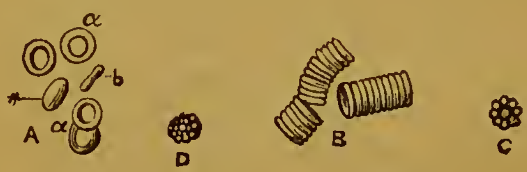


Fig. 22.—Human Blood Corpuscles.

A. When freshly drawn—*a*, as seen on the flat; *b*, as seen edgewise; *, three-quarter view.
B. Forming rouleaus, by adhering on their flat surfaces like piles of coin.
C. As altered by exposure to air.
D. A lymph globule, or colourless blood corpuscle.

Composition of the Blood.—The chemical composition of the blood varies with the age, sex, and constitution of the individual, also at different periods in the same individual, according to the state of health, exercise, and time after meal. Repeated bleeding also greatly alters the composition of the blood, producing a great diminution in the number of the red corpuscles, and a corresponding increase in the quantity of the serum, or fluid portion. The blood of men

contains a greater number of red corpuscles and less water than that of women.

The composition of 1,000 parts of human blood may be expressed with sufficient accuracy in round numbers as follows:—Water, 780; globulin, 140; albumen, 70; fibrin, 2; fatty matters, $1\frac{1}{2}$; extractives, $6\frac{1}{2}$.

Each red corpuscle has the form of a double concave lens, such as those used in the construction of the spectacles of short-sighted persons. These cells are now regarded as non-nucleated. Should you possess a microscope, or have access to one, prick your finger with a very fine needle, place the minute drop which exudes and adheres to the point of the needle under the microscope, covering it with a very thin piece of glass or a piece of talc to keep it from the air; look at it carefully, and you will observe all the appearances shown in the diagram. (See Fig. 22.) Some idea of the minuteness, and of the immense multitude of these corpuscles may be gathered from the fact that it is estimated that one cubic inch of freshly drawn, healthy human blood contains about 84,000,000 of red corpuscles and 240,000 white or colourless corpuscles.

The blood corpuscles of the mammalia are in general circular. The red corpuscles in the blood of reptiles are in general oval, and comparatively large.

In the case of suspected murder a skilful anatomical microscopist can distinguish human blood stains from red paint or red stains; also from the blood stains of other animals, by the shape, size, and general microscopic character of the adhering red corpuscles. The blood of the mollusca does not contain red corpuscles.

Structure of the Red Corpuscles.—A red corpuscle most probably consists of a delicate cell-wall enclosing a homogeneous, semi-fluid substance,

and is composed of two proximate chemical principles —globulin and hæmatin (the red colouring principle of blood),—the properties and composition of which have been previously described.

Functions of the Red Corpuscles.—The red corpuscles absorb oxygen, which they carry to and distribute through the tissues of the various organs, developing and stimulating their vital activity; hence they have been termed oxygen-carriers. Blood deprived of its corpuscles will only dissolve 1-13th of the quantity of oxygen it will dissolve in its natural state. The red corpuscles do not themselves pass out of the capillaries, and cannot reach the tissues; but they give up the dissolved oxygen, which passes through the walls of the capillaries to the tissue by the action of osmosis.

Development and Decay of the Red Corpuscles.—The red corpuscles are generally supposed to originate from the lymph or chyle corpuscles, which develop into the coloured blood corpuscles. The red corpuscle, having performed its functions, dies, degenerates like other tissues, and liquefies. It was formerly thought that the red corpuscle gave birth to new ones of the same kind, but this view is now generally discarded.

The White or Colourless Corpuscles of the blood are contained in the blood of all animals, the invertebrata included. (See D, Fig. 22.)

They are minute, globular, transparent, or slightly pearly, colourless, nucleated bodies, about the same size or a little larger than the red corpuscles. Their surface presents a peculiar roughened appearance. They consist of a very delicate external cell-wall, enclosing a nucleus, a nucleolus, and granular matter. These parts are rendered more distinct by the action

of dilute acetic acid, which dissolves the granular matter. The white corpuscles of the blood are also a little larger than the lymph corpuscles, which contain no cell-wall; they are about the 1-2,500th of an inch in diameter. In healthy human blood the white corpuscles are in the proportion of about 1 to 300 of the red corpuscles; but their number varies to a certain extent, according to the time of the day at which the experiment is made, being invariably greater after than before a meal.

Functions.—The functions of the white corpuscles have not been certainly determined, but most modern physiologists regard one of their principal functions to be the development of the fibrin of the blood, or the conversion of the albuminous substance of that fluid into fibrin, which is regarded as the principal "plastic" and true nutrient compound of the blood. Another function which is attributed to the white corpuscle is the perfecting and development of its nucleus, which ultimately becomes a red corpuscle.

The Liquor Sanguinis (L., *sanguis*, blood) **or Blood Plasma** (Gr., *plasso*, I form) is the clear colourless liquid in which the red and white corpuscles float. It consists chiefly of an alkaline solution of albumen and fibrin mixed with dilute solutions of other salts, as chloride of sodium, tribasic phosphate of soda, and a small but varying proportion of fat.

Functions of the Liquor Sanguinis.—The liquor sanguinis serves as the medium by which the red corpuscles or oxygen-carriers are floated through the vascular system, and supplies the plastic or nutrient materials necessary to the development and repair of the tissues.

The Vital Properties of the Blood are its power of coagulation, also, probably, a certain amount

of formative and self-maintaining power, and a limited capacity of self-purification through the elimination of morbid or even mineral poisons, as in certain fevers. The vital properties of the blood probably reside in its fibrin and corpuscles.

Coagulation of the Blood (L., *coagulo*, I curdle).—When healthy human blood drawn from the body into a cup or basin is left to itself it gradually coagulates, or separates into two portions—an upper liquid portion, termed the serum, and a lower gelatinous substance of greater or less firmness, termed the cruor, clot, or crassamentum. Coagulation usually commences from three to five minutes after the blood is withdrawn from the body, the clot continuing to contract for ten or twelve hours subsequently.

During coagulation the whole of the blood at first assumes a gelatinous appearance ; then, as the clot contracts, drops of serous fluid gradually begin to ooze out. These drops slowly increase in number and quantity, unite, and cover the gelatinous clot with a layer of straw-coloured liquid ; this layer, which consists of serum, becomes deeper and more abundant as it is squeezed out by the gradual contraction and hardening of the crassamentum or clot.

The following table shows the composition of blood after coagulation :—

Coagulated Blood	Serum	Albumen.
		Salts.
		Water.
	Clot	Fibrin.
		White corpuscles.
		Red ,,

When a very thin slice of the clot is examined by the aid of a microscope it is seen to consist of a network of white fibres enclosing corpuscles in its meshes.

If the clot be washed in a stream of water the corpuscles are washed out, and the white fibrous network or fibrin alone remains.

The Serum (*L.*, *serum*, whey) is the colourless or pale straw-coloured, greasy, viscid, albuminous fluid which separates from the clot during coagulation. It consists of the liquor sanguinis deprived of its fibrin. When heated to 160° Fah. or upwards it coagulates, a small quantity of uncoagulable liquid, termed the serosity, exuding during the process.

The Serosity (*L.*, *serum*, whey) is the thin, aqueous, saline solution which remains after the separation of the albumen from the serum by the process of coagulation. It consists of water holding the salts of the serum in solution.

The Cruor, Crassamentum, or Clot, is the more or less firm, gelatinous, dark red substance which separates from the blood during the process of coagulation. It consists of fibrin and the red and white blood corpuscles, the fibrin having spontaneously assumed the form of a network, enclosing the corpuscles within its meshes. When the blood coagulates very slowly, or there is a deficiency of the red corpuscles, the upper part of the clot is of a yellowish white colour.

The Cause of Coagulation is at present unknown. Some physiologists regard it as a vital process, while others regard it as the death of the blood.

In cases of murder attempts are sometimes made to disguise the mode in which the crime has been effected by inflicting wounds in the throat or other parts of the body after death; but this ruse will not deceive the physiologist; living blood only coagulates. Hence if there is clot, the wound was inflicted during life; if, on the contrary, there is no clot, the wound was inflicted after death.

The cessation of bleeding, internal or external, and the adhesion of the opposite surfaces of incised wounds, is consequent on the coagulation of the blood.

Gases in the Blood.—The living blood always contains oxygen, nitrogen, and carbonic acid gases; also traces of ammonia. 100 vols. of human blood contain about 16 vols. of oxygen, 1½ of nitrogen, and 29 of carbonic acid, in a free or uncombined state—that is, simply dissolved, but not chemically combined with the blood.

CIRCULATION AND THE ORGANS OF CIRCULATION.

The bloodvessels with the light cross-markings are systemic arteries, and may be coloured red.

The great systemic artery, the aorta, arises from cavity No. 4, concealed by the pulmonary artery. From the convexity of the arch which it forms, are given off—first, the brachiocephalic, or right arm and head artery; second, the left carotid to the left of the head; and third, the left subclavian for the left arm.

The corresponding veins unite to form the vena cava superior.

The aorta now turns down in front of the spine, and divides on the fourth lumbar vertebra into the common iliac arteries; these divide into the internal and external iliacs, the latter being the artery for the inferior extremity.

The pulmonary artery, arising from No. 2, is marked with dotted crossed lines.

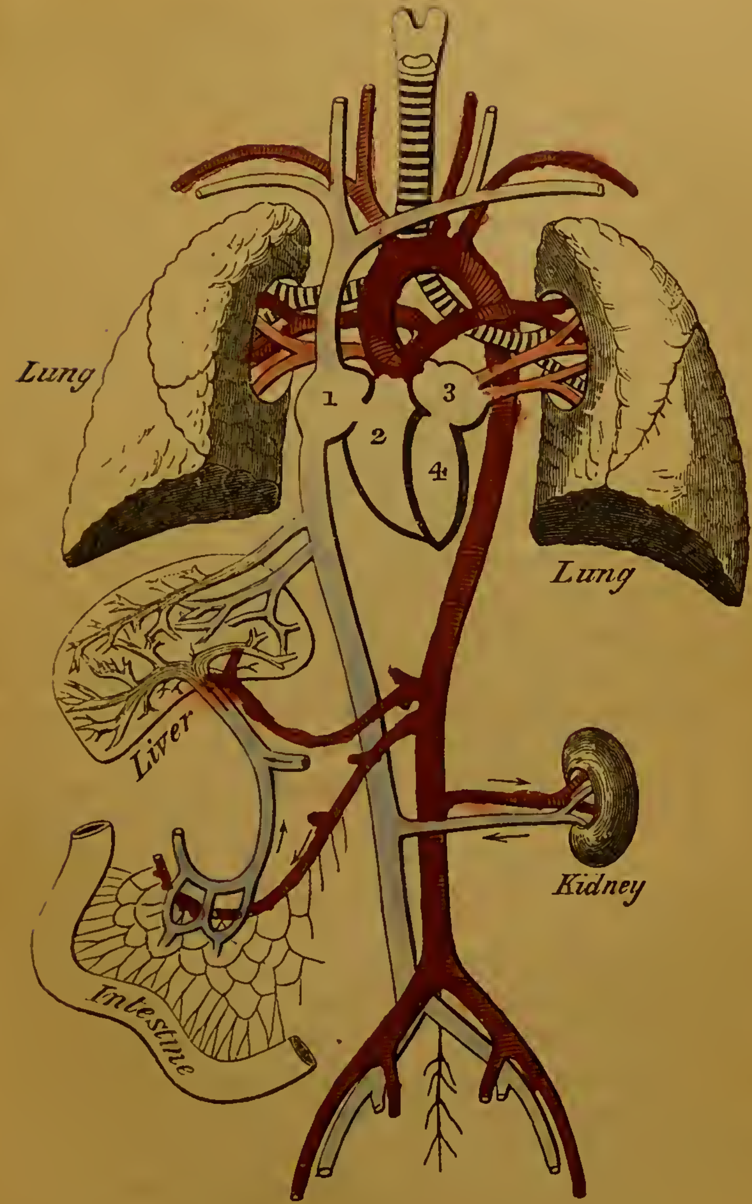
The clear vessels are the veins.

Those connected with No. 1 of the heart may be coloured with blue.

Those joining No. 3, are the pulmonary veins, and are seen, two in number, at the lower part of the root of each lung. The pulmonary veins may be coloured red.

The dark tube, with strong cross-markings leading to each lung, is the windpipe, surmounted by the larynx.

The liver is seen to receive a large vein, the vena porta, in addition to its artery, which is small. The returning veins, or veins proper, of the liver are seen entering the vena cava inferior.



1. Right auricle. 2. Right ventricle. 3. Left auricle. 4. Left ventricle.

Every thought we think, every movement, however slight, we perform, though but the moving of a finger or an eyelid, is attended with the destruction or waste of the nervous, muscular, and other tissues, just as every ray of light or heat which is emitted from the burning candle is attended by the combustion and consequent destruction of its particles. These tissues therefore require incessant repair and renovation. Even during the period of sleep, when we are in the state of most perfect bodily and mental repose, numerous physical, chemical, and vital actions pursue an unceasing round, producing an equally incessant course of waste and decay, and necessitating the operation through the whole system of an equally conspicuous counter-process of nutrition and repair. Not only is it necessary that the tissues in the various parts of the body should be sufficiently and continuously nourished; but it is equally necessary that they, and more especially the nervous and muscular tissues, should be supplied with the stimulus of oxygen, otherwise they would be entirely unable to perform their functions. The regular and continued supply of nutritive material and of oxygen to every part of the living body, and the immediate removal of the disintegrated or waste tissues, are effected through the process of circulation.

Circulation is the process by which the blood or nutritive fluid is carried out from and returned to the heart from the various parts of the body.

The Organs of Circulation are the heart, the arteries, the veins, and the capillaries.

The Heart, which acts as a sort of force-pump, and is the principal organ of circulation, consists of a hollow conical muscular bag, which is connected with the principal bloodvessels. (See Diagram, page 125,

also Figs. 8, 24, and 30.) It contains four cavities or chambers, the walls of which dilate and contract independently of the will.

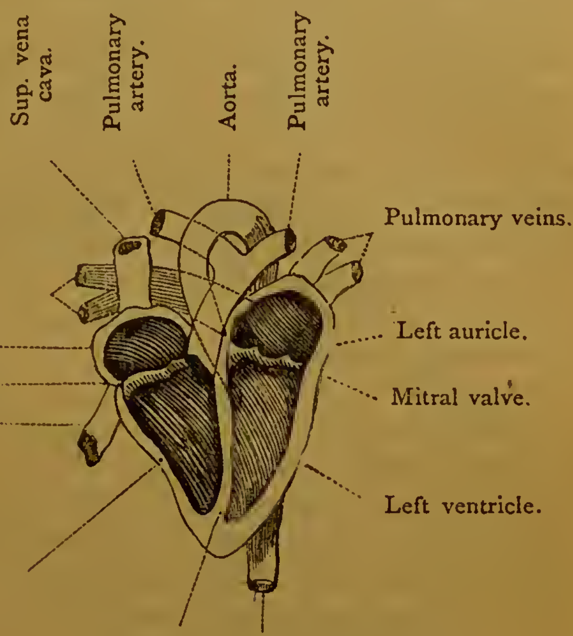


Fig. 23.—THEORETICAL SECTION OF THE HUMAN HEART.

It is situated in the centre of the thorax, between the lungs, and on a level with the lower 2-3rds of the sternum, lying obliquely forward and to the left. Its lower end or apex beats against the walls of the chest in the space between the fifth and sixth ribs, between two and three inches to the left of the sternum, where its action can be most distinctly felt.

The heart of an adult man is about 5 inches long, $3\frac{1}{2}$ inches broad, and $2\frac{1}{2}$ inches thick, or about the size of a man's fist, and weighs 10 to 12 ounces. It continues to increase in size till late in life.

Pericardium (Gr., *peri*, round, and *cardia*, the

heart).—The heart is suspended by the large vessels which proceed from its summit within a fibro-serous bag or sac termed the pericardium. This membrane, like the rest of the serous membranes, consists of a closed sac, one portion of which is reflected, or as it were tucked into the other. The reflected portion adheres to and invests the heart, forming its proper tunic. Inflammation of this membrane is termed pericarditis. The general arrangement of this membrane resembles that of the pleura.

Structure of the Heart.—The heart is composed of striated muscular fibre. It contains two upper cavities termed right and left auricles, and two lower cavities or chambers termed right and left ventricles. The two auricles are separated by a septum, or dividing wall, termed the septum auriculorum. The two ventricles are also separated by a partition termed the septum ventriculorum. The right auricle communicates with the right ventricle, and the left auricle with the left ventricle, by openings termed respectively the right and left auriculo-ventricular openings, but the right and left sides of the heart do not communicate directly with each other. Each of these openings is surrounded by a fibrous ring termed the zona annularis, and is furnished with a valve to prevent the return of the blood. (See Figs. 23 and 24.) The tricuspid valve prevents the blood from passing backward from the right ventricle to the right auricle; the bicuspid or mitral valve in the left side of the heart prevents the blood from passing backward from the left ventricle to the left auricle. The valves are composed of serous and fibrous membrane; they are attached at their lower extremities to the walls of the heart by little tendinous cords termed cordæ terminæ; otherwise they would flap through into the auricles, offering no

resistance to the return of the blood. The inside walls of the heart are covered with little fleshy columns termed *carneæ columnæ*, which stand solidly out from their sides. Some of these fleshy columns are attached to the walls at their base only, their upper extremities

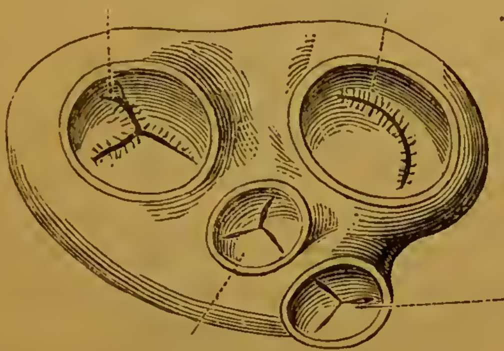


Fig. 24.—Upper Surface of the Heart, the Auricles having been Dissected away to show the Valves.

being attached to the cordæ tendineæ of the valves only; these are termed *columnæ papillares*, or papillary columns. They probably regulate the action of the tendinous cords and the valves. These structures may be readily observed by examining the interior of a sheep's heart.

The right auricle communicates with the upper vena cava by an opening which is not guarded by any valve, the weight of the descending column of blood acting as a substitute for a valve; and with the lower vena cava by an orifice guarded by three semilunar folds, forming the Eustachian valve. The right ventricle communicates with the pulmonary artery, the orifice of the artery being guarded by the pulmonary valve, also consisting of three semilunar folds. The left auricle communicates by four orifices, having no

valves, with the four pulmonary veins; the left ventricle communicating with the aorta, its orifice being guarded by the aortic valve, which consists of three semilunar folds.

The heart is nourished by blood supplied by the two coronary arteries which leave the aorta immediately above the aortic valve.

The Nerves of the heart are derived from branches of the pneumogastric nerve; it is also well supplied with nerves from the sympathetic system, in addition to which it is furnished with small ganglia.

The heart of reptiles contains three chambers only, viz., one ventricle and two auricles, a part of the venous blood only passing to the lungs to be aërated. The heart of fishes is still more simple, containing but two cavities, an auricle and a ventricle.

Action of the Heart.—The heart pursues an unwearied and unceasing round of exertion, alternately contracting and dilating from the first moment of existence to the latest period in life. It has been calculated that the heart beats some 3,000,000,000 times, and propels some 500,000 tons of blood through its chambers, in the course of an ordinary life. The venous blood passes (see Figs. 23 and 25)—1, from the venæ cavæ into the right auricle; 2, the right auricle contracts and propels the blood forward to the right ventricle, which dilates to receive it, the tricuspid valve opening meanwhile; 3, the right ventricle then contracts (the tricuspid valve closing) and drives the blood through the pulmonary artery into the lungs, where it is aërated, without which change it cannot return to the heart; 4, the aërated, revitalized blood returns by the four pulmonary veins to the left auricle, which contracts and drives the blood into the left ventricle, the mitral valve opening and the ventricle dilating to

receive it; 5, the left ventricle now contracts, driving the blood through the aorta into the system, its regurgitation being prevented by the closing of the aortic valve.

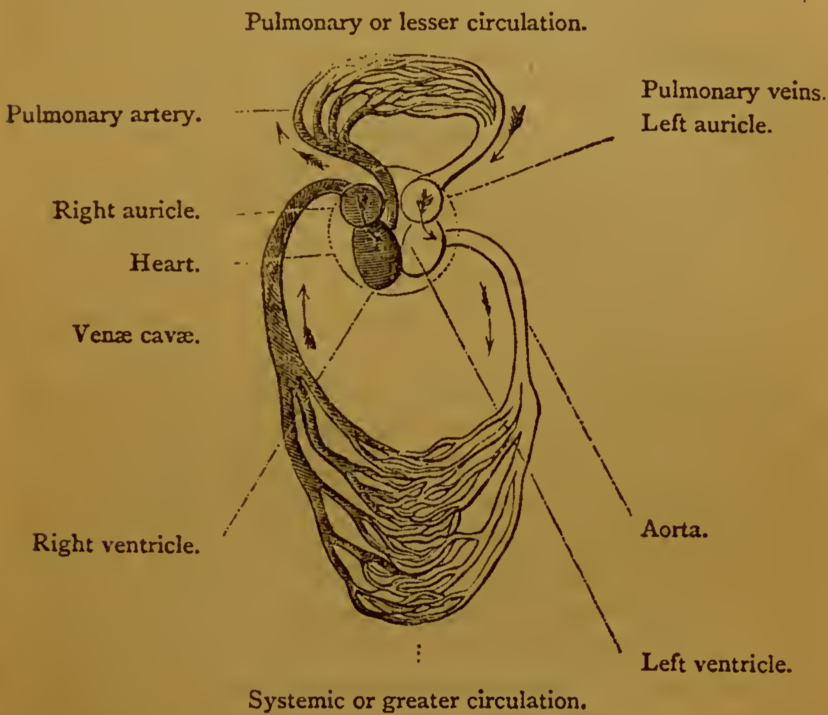


Fig. 25.—THEORETICAL DIAGRAM OF CIRCULATION OF MAN AND THE MAMMALIA.

Greater, Lesser, and Portal Circulation.—It will thus be observed that the heart is the centre of two processes of circulation—the one termed the lesser pulmonary or respiratory circulation, whose object is the aëration of the blood; the other the greater or systemic circulation, whose object is the nutrition and stimulation of the entire organism. The process by which the liver is supplied with venous blood from the

organs of digestion for the elaboration of the bile is termed the portal circulation.

Systole (Gr., *sustello*, I contract).—The two auricles contract simultaneously, their contraction being termed their systole. The ventricles also contract simultaneously, their systole commencing just as that of the auricles is terminating. The heart contracts with a force of about 4½ lbs. on the square inch, and sends out 3 to 4 oz. of blood at each contraction.

Diastole (Gr., *dia*, apart, and *stello*, I send).—The auricles dilate simultaneously, also the ventricles, this action being termed their diastole. The diastole of the ventricles also commences just as that of the auricles terminates.

Sounds of the Heart.—If the ear be applied to the chest immediately over the region of the heart two distinct sounds will be preceived. The first is a prolonged dull sound, which has been compared to the articulation of the word *lubb* or *loobb*; this is followed by an interval of silence; at the termination of this interval the second, a shorter and sharper sound, which has been compared to the articulation of the syllable *dup*, is heard. The exact cause of these sounds is still a subject of discussion among physiologists. By means of the stethoscope the physician can distinctly hear the sounds in the interior of the heart, and thus ascertain, by the working of its valves, its condition of health or disease.

Course of the Blood.—The blood leaving the left side of the heart passes out by the aorta, or principal artery, into the general arterial system, by which it is conveyed to the capillaries, which distribute it through the tissues; it is then collected by the veins and returned to the right side of the heart by the venæ cavæ.

TABULAR VIEW OF THE COURSE OF THE BLOOD.

Arteries.		Veins.	
To the Lungs	2 pulmonary arteries.	*From the* Lungs	4 pulmonary veins.
Head	Carotid arteries.	Head	Jugular veins, venæ innominatæ, and superior vena cava.
Upper extremities	Aorta, subclavian, axillary, brachial, ulnar, radial, palmar, and digital arteries.	Lower extremities	Digital, plantar, tibial, popliteal, femoral, and saphenous veins.
Trunk and its viscera	Aorta, intercostal, and abdominal arteries; cœliac axis; gastric, hepatic, and splenic arteries; superior and inferior mesenteric, and common, external, and internal iliac arteries.	Trunk and its viscera	Common, external, and internal iliac veins; mesenteric, splenic, gastric, portal, abdominal, and intercostal veins, and inferior vena cava.
Lower extremities	Femoral, popliteal, peroneal, back and front tibial, plantar, and digital arteries.	Upper extremities	Digital, palmar, ulnar, radial, brachial, axillary, and subclavian veins; venæ innominatæ, and superior vena cava.

The principal arteries and veins only are given in the above table.

The Arteries (Gr., *aer*, air, and *tereo*, I keep) were supposed by the ancients to contain air because they were usually found empty after death. They are cylindrical, tough, elastic, flexible tubes, which receive the pure aërated blood from the heart, and carry it out and distribute it to the capillaries, which diffuse it through the various glands and tissues for the purposes of nutrition and secretion. (See Fig. 26.)

If an artery be violently torn, as when a limb is pulled off by machinery, the ends of the arteries curl inwards, stopping the aperture of the torn artery, and preventing the escape of the blood, so that sometimes scarcely a drop is lost from the larger vessels. The

aorta, or principal artery of man, is nearly an inch in diameter; that of the whale is said to be upwards of three feet in diameter.

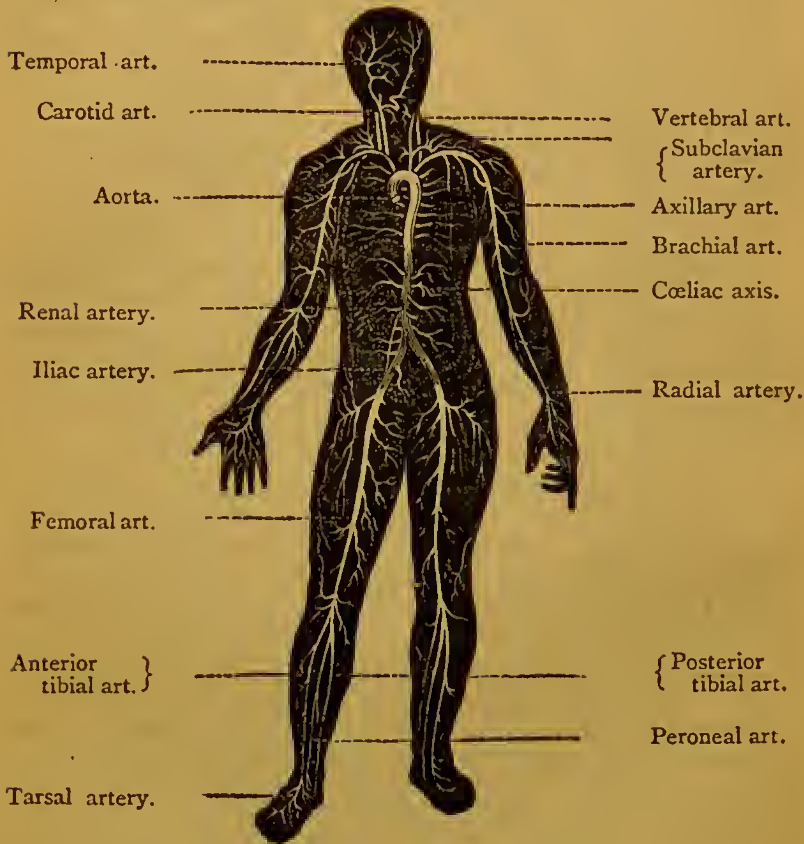


Fig. 26.—Theoretical Diagram of the Arterial System of Man.

The arteries, with the exception of the pulmonary arteries, contain pure bright red blood, which is therefore generally termed arterial blood. The walls of the arteries consist of three coats:—

(1.) An external tough whitish coat of areolar tissue.

(2.) A middle elastic coat, composed of yellow elastic fibrous tissue and unstriped muscular fibre.

(3.) An inner elastic and epithelial coat.

The arteries commence in the heart, and terminate in the capillaries. The walls of the arteries are nourished by blood supplied by minute arteries which enter and ramify in their structure. They are also supplied with nerves from the sympathetic system.

Anastomosis of the Arteries and Veins.—The arteries and veins anastomose (Gr., *ana*, through, and *stoma*, a mouth), divide, open into, and communicate very freely with each other, as seen in the veins at the back of the hand. If a ligature be tied round one of the principal arteries of a limb, so as to obstruct the passage of the blood, the temperature of the limb will fall considerably ; but after a time the limb will again become warm, showing that the circulation has become re-established through the medium of the other branches of the tied artery.

The Pulse, or beating of the arteries, which may be felt most conveniently at the wrist, is caused by the contraction of the heart. Medical men examine the pulse to ascertain the rate of movement of the heart. The rapidity of the pulse increases with exertion or excitement, is greater when standing than sitting, and when sitting than lying down, and becomes exceedingly rapid during fever. The following table shows the rates of pulsation at different periods of life :—

In the infant,	130	to	140	per minute.
„	adult,	70	„	80	„
„	aged,	50	„	60	„

It is said by some that in advanced age there is a general increase in the rapidity of the pulse.

The pulse is caused by the sudden extension or elongation of the extensible, elastic artery by the sudden propulsion of fresh blood into it by the heart's

contraction. Its elasticity causes it immediately to contract or shorten to its original dimensions, again to be distended by a fresh propulsion of blood and a new pulsation, the phenomenon being repeated while life endures.

Movement of the Blood in the Arteries.—It has been calculated that the blood moves through the arteries at the rate of twelve inches per second, and makes the entire circuit of the body in about thirty seconds. It moves more rapidly during youth, diminishing in velocity as age advances. The rapidity of the circulation is increased by muscular and mental exertion, and under the excitement of the passions and the emotions.

Wounded Artery.—A wounded artery may readily be distinguished from a vein by the bright red colour of the blood which issues from it, and by the force, rapidity, and jerking of the current. When an artery is wounded, a small stone or other hard body should be placed over the artery immediately before the wound, and between it and the heart. A handkerchief or cord should then be tied over the stone, just above the wound, and twisted very tightly, so as to compress the part immediately before the wound, and between it and the heart, the object being to stop the flow of the blood which moves from the heart to the wound. It is useless to tie a wounded artery beyond the wound, since the blood flows directly from the wound to it, and does not return by the arteries. By attention to this simple expedient, many lives which would otherwise be lost might be saved.

A wounded vein should be tied on the opposite side of the wound—that is, just beyond the wound, —since in the veins the blood flows to the heart.

Remember, then, that the blood in the arteries flows from the heart, and in the veins to the heart.

The Capillaries (L., *capillus*, a hair) are microscopic cylindrical tubes which receive the blood from the arteries and distribute it through the tissues. They consist of an extremely delicate homogeneous membrane containing embedded nuclei. The largest capillaries are invested with fine longitudinal and transverse elastic fibres, and approximate in structure to the arteries and veins.

The smaller capillaries do not admit of the passage of the red corpuscles. The liquor sanguinis exudes or passes through the walls of the capillaries by osmosis into the surrounding tissues, and nourishes them. The blood moves through the capillaries with uniform velocity.

The sectional area of the capillaries has been estimated at 400 times that of the arteries; the blood therefore moves through them with 400 times less velocity than through the arteries, or at the rate of $1\frac{3}{4}$ inches per minute.

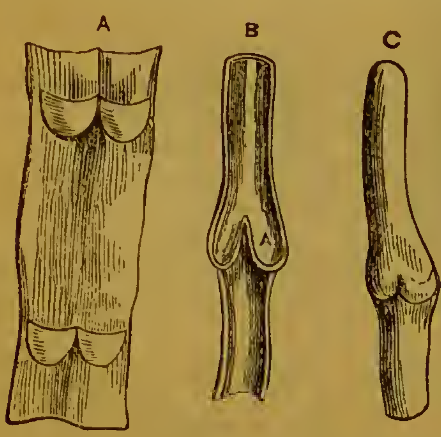
A. Small vein large enough to admit several blood-globules abreast.
B, B′. Capillaries admitting but a single series of blood corpuscles.
C, C′. Epithelium cells covering skin.

Fig. 27.—Network of Capillaries.
Portion of web of frog's foot magnified.

The Veins, or bloodvessels which return the blood from the capillaries to the heart, correspond in general structure and arrangement to the arteries. With the exception of the pulmonary veins, they contain impure, dark, venous blood. They commence in small twigs, formed by the junction of the capillaries; these twigs join together, until, after repeated junctions, they form the larger veins, these again ultimately uniting to form the vena cava, or principal trunk vein, which pours the blood into the heart.

The veins are larger and more numerous than the arteries; but the walls of the former are thinner and more transparent than those of the latter, as seen in the veins at the back of the hand, which permit of the colour of the dark venous blood showing through.

The veins, like the arteries, contain three coats; they differ from the arteries principally in the greater thinness of the middle elastic coat. They are described as deep, superficial, and sinuses (as found in the skull). They commence in the capillaries and terminate in



A. Vein slit open, showing pocket-shaped valves.
B. Valves closed by pressure of blood from behind.
C. Outside of vein, showing expansion over the seat of a valve.

Fig. 28.—Semilunar Valves.

the heart. The veins are nourished by blood supplied by the vasa vasorum. The movement of the blood is slower in the veins than in the arteries.

The Valves of the veins, shown in Fig. 28, A, B, C, consist of pocket-shaped or semilunar folds of fibrous membrane and epithelium from the inner coat of the vein. These valves are so arranged that when the blood attempts to pass backward the membranous folds of which they are composed become distended, press against each other, and close the passage, thus preventing the regurgitation of the blood. Fig. 29 shows the action of these valves.

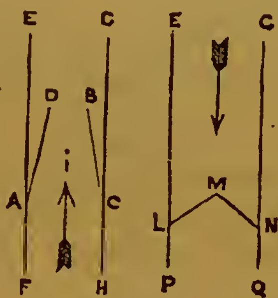


Fig. 29.—PLAN SHOWING THE ACTION OF THE VALVES OF VEINS.

1. The valves open to allow of the blood passing toward the heart; A D, and C B, the valves; E F, and G H, the sides of the vessel; I, the central channel.
2. The valves closed by the pressure of the blood from behind; E P, and G Q, the sides of the vein; L M, and N M, the valves. The arrows indicate the direction of the currents.

Forces of the Circulation.—The chief forces which develop and maintain the circulation are,—

(1.) The contractile force of the heart. This has been termed the primum mobile (main spring) of the circulation; it is also designated a "*vis à tergo*" (force from behind or pushing force).

(2.) The contractibility of the arteries.
(3.) The muscular compression of the veins produced by exercise. During exercise the veins are compressed, and a portion of their contents expelled: this portion can only move forward in the direction of the heart, because of the obstruction of the valves.
(4.) A selective force, sometimes termed a capillary force, due to the attraction of the tissues or the glands for the constituents of the blood. In the lower animals the capillary circulation is probably maintained almost entirely by this force, which has been termed a "*vis à fronte*" (force in advance).

RESPIRATION AND ORGANS OF RESPIRATION.

Respiration is the process by which the dark venous blood is purified by being brought into contact with the oxygen of the air. Carbonic acid gas, watery vapour, and organic matter are excreted during the process.

The Lungs.—The principal seat of this process in the higher animals is the lungs (see Figs. 8, 30, and 35), which consist of an arrangement by which a very large surface of blood is exposed, through the medium of a very thin membrane (not more than 1-1,000th of an inch in thickness), to a very extensive surface of air.

EXPERIMENT I.—Breathe on to the surface of a bright mirror; it immediately becomes covered with minute drops of water, showing that watery vapour is evolved from the lungs in breathing.

EXPERIMENT II.—Breathe through lime water for a few seconds, taking care to prolong the expiration as much as possible after each breath. The solution

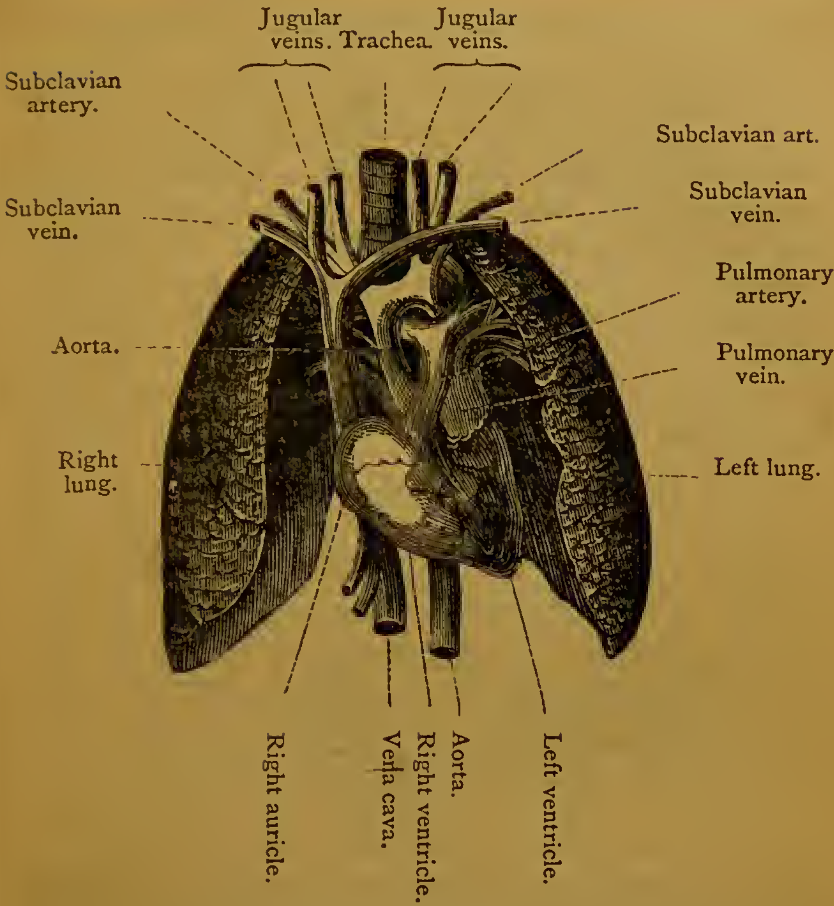


Fig. 30.—Lungs, Heart, and Principal Bloodvessels of Man.

will become quite white and turbid, showing that carbonic acid gas has been expired during the process of breathing out.

Experiment III.—If the breath be passed gently for a short time through strong oil of vitriol, the vitriol becomes blackened, thus proving the presence of organic matter in the breath. No young or in-

experienced student should perform this dangerous experiment.

Changes in Expired Air.—From the above experiments it will be seen that the expired air contains considerable quantities of carbonic acid and watery vapour; also traces of organic matter, which are exceedingly prone to putrefaction. Respired air is also said to contain traces of ammonia and hydrogen. Though respired air is rendered impure and injurious by the presence of these impurities, yet it is rendered far more deleterious by the simultaneous removal of the oxygen.

COMPOSITION OF ATMOSPHERIC AIR.

	Pure.	Respired.
Oxygen . . .	20·61	16·26
Nitrogen . .	77·95	77·95
Carbonic acid . .	0·04	4·39
Aqueous vapour .	1·40	1·40
	100·00	100·00

The above table presumes that the quantity of watery vapour remains unchanged, which is not the case. The actual quantity of the carbonic acid and watery vapour evolved during respiration varies very greatly with temperature, exercise, health, &c. Dr. Smith found an increase of two cubic inches of carbonic acid per minute for every 1 lb. weight carried by a soldier in marching order.

Changes in the Blood by Respiration.—When the blood enters the lungs it is of a dark purplish colour, very impure, quite unfitted for the repair of the tissues or the support of life, and highly charged with carbonic acid gas. When it leaves the lungs it has

assumed a bright scarlet colour, has parted with most of its carbonic acid, has absorbed a large quantity of oxygen, and acquired power to repair the wasted tissues, and to stimulate and sustain the various processes of life. In other wrods, respired or aërated blood has lost carbonic acid, become highly oxygenized, and acquired powerful reparatory and vivifying properties.

The principal agents in the absorption of oxygen are the blood corpuscles, which have therefore been designated oxygen-carriers.

The Change of Colour in the blood has been ascribed by Liebig to the presence of iron in this fluid. He supposes it to be present in the venous blood in the form of protocarbonate of iron. When this substance is exposed to the action of the air in the lungs he assumes that it is decomposed into protoxide of iron and carbonic acid gas, the latter being evolved during respiration; while the protoxide of iron, combining with an additional quantity of oxygen, is converted into sesquioxide of iron, which communicates to arterial blood its characteristic bright scarlet colour. This theory is not now so generally received as formerly.

Source of the Carbonic Acid.—The carbonic acid is not formed in the lungs, as was formerly supposed, but most probably in the interstices of the tissues throughout the whole of the organism. The greater part of the oxygen absorbed during respiration is probably absorbed by the red corpuscles of the blood, and carried by them to every part of the system. Then, passing through their walls by osmosis, it enters the interstitial spaces in the tissues, and there meets and combines with the carbon of the partially disintegrated or wasted tissues, producing carbonic acid.

The oxygen before combination, and the carbonic acid the result of that combination, are both supposed to be held in solution in the intercellular fluid which more or less abundantly pervades all the living tissues.

The oxygen dissolved in the arterial blood is supposed to pass through the walls of the capillaries by the action of exosmose, while the carbonic acid produced by the combination of the oxygen with the carbon of the waste tissues passes into the capillaries by the process of endosmose. The arterial blood, thus losing most of its oxygen, and receiving much carbonic acid, is converted into venous blood, and returned to the lungs to be repurified and revitalized.

A portion of the carbonic acid evolved during respiration is, however, supposed to be formed by the direct combination of the respired oxygen with carbon contained in the blood, this carbon being derived from the food and not from the tissues.

Reasons for the above Theory.—1. Place a frog, or other animal not readily suffocated, in a glass receiver filled with nitrogen, or any other respirable gas not containing oxygen. If the gas respired by the frog be analyzed at various intervals, it will be found that as much carbonic acid has been expired by the frog as it would have expired had it been duly supplied with atmospheric air. Hence, in the absence of oxygen to combine with the carbon, the carbonic acid, if present, must have previously existed already formed in the blood. Hence the carbonic acid is not formed in but excreted by the lungs.

2. If oxygen, nitrogen, and some other gases be passed through venous blood drawn from any part of the body, carbonic acid gas will be evolved. Hence venous blood is charged with carbonic acid before it reaches the lungs.

3. When oxygen unites chemically with carbon, hydrogen, or any other elementary substance, much heat is evolved. Hence if these bodies entered into combination solely, or even principally, in the lungs, these organs would become much hotter than other parts of the body. But this is not the case, the temperature of all parts of the body being nearly uniform. Hence the temperature produced by these combinations being nearly uniform all through the body, the probability is that these chemical combinations also take place throughout the tissues of the living organism.

Mechanical and Physical Respiration.—Having explained the nature and objects of respiration as a vital process, it becomes necessary to describe the mechanical agents by which this process is effected. The principal mechanical agents by which respiration is effected are the thorax and the lungs.

Structure and Movements of the Thorax.—The thorax, or chest, consists of an airtight box, with moveable walls and flooring, containing but one opening. When these walls recede from each other the chest is enlarged laterally in every direction. When its floor is depressed it is enlarged vertically. By the combination of these two movements, lateral and perpendicular, its internal capacity is greatly enlarged or reduced. When the chest is enlarging, air rushes in by virtue of atmospheric pressure; this constitutes inspiration. When it is contracting air is expelled; the latter constitutes expiration.

The thorax, or chest, which is somewhat of the form of a beehive, is situated in the upper part of the trunk, extending from the shoulders to the bottom of the lowest rib. It is formed of the 12 dorsal vertebræ, 24 costæ or ribs, with their cartilaginous appendages, and the sternum or breast-bone. These together form

an open cage or framework, giving strength and resistance to the whole structure. The spaces between the

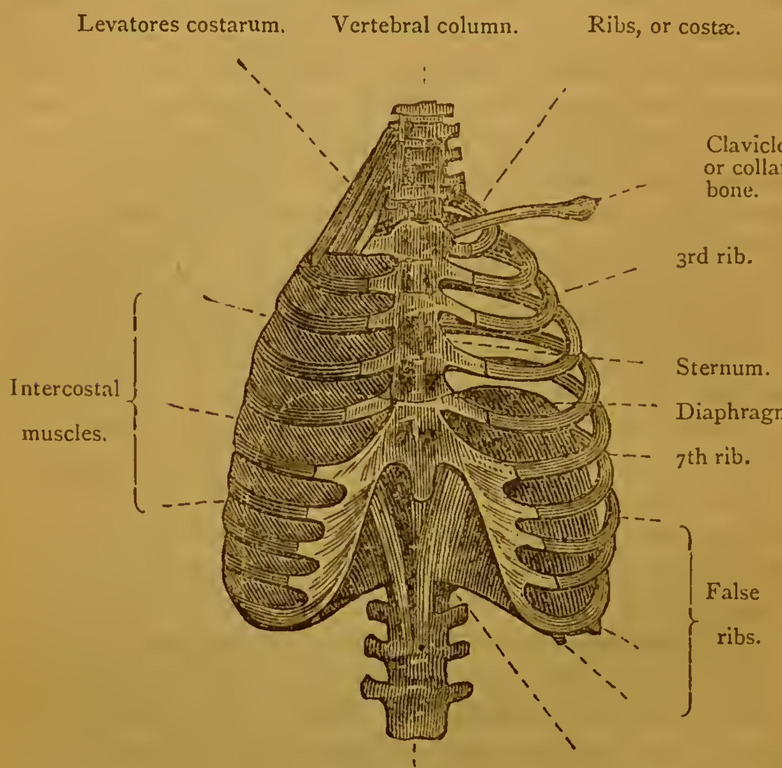


Fig. 37.—The Thorax with its Principal Muscles.

ribs or costæ (intercostal spaces) are filled up by the intercostal muscles; these, together with the bony framework, form unbroken walls, constituting the sides or walls of the thorax. The floor of the thorax is formed by the diaphragm (see Figs. 8 and 31), a large, thin, membranous muscle, which stretches across the lower part of the thorax, separating it from the abdomen, of which it constitutes the roof, thus dividing

the trunk into two parts. This muscle, the diaphragm, is attached in front to the sternum or breast-bone, behind to the vertebral column, and on every side to the lower ribs. It is arched, or dome-shaped, being convex above and concave below. Its attachments to the vertebral column, ribs, and sternum are all air-tight; but it is perforated to admit of the passage of the alimentary canal, bloodvessels, and nerves, to the abdomen. Its junctions with these walls, and with the canals and tubes which pass through it, are also airtight. It is tendinous at its centre, and when it contracts flattens out so as to press the contents of the abdomen downwards and outwards, and thus to enlarge the cavity of the chest.

Movements of Respiration.—Inspiration, or the drawing in of air by the lungs, is caused by the lateral, vertical, and antero-posterior enlargement of the cavity of the chest, the air rushing in through the windpipe to fill what would otherwise form a partial vacuum. The ribs—which, for the sake of illustration, may be considered to be so many parallel bars—are attached by their heads to the vertebral column, so as to form with it a double obliquity, or inclination, viz., a lateral and an antero-posterior obliquity, respectively shown by Figs. 32 and 33.

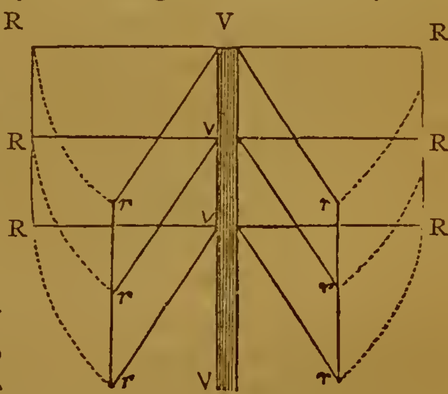


Fig. 32.—Plan of Portion of Back of Thorax.

Let the parallel oblique lines, marked *r* V (Fig. 32), represent a back view of three pairs of ribs in the position of repose—that is, inclined laterally to the

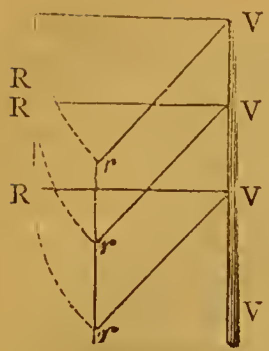


Fig. 33.—PLAN OF PORTION OF SIDE OF THORAX.

vertebral column V V. When the levatores costarum (elevators of the ribs) and the intercostal muscles (see Fig. 31) contract they raise the ribs to a nearly horizontal position, represented by the lines R V, the end (*r*) of each rib describing an arc, represented by the dotted line. In this latter position it will be seen that the ends, R R, of the ribs are removed to a greater distance from the back-bone and from each other; the cavity of the chest is therefore enlarged laterally.

Let the parallel oblique lines, marked *r* V (Fig. 33), represent a side view of three ribs inclined antero-posteriorly (front to back) to the vertebral column V V. When the ribs are brought to a nearly horizontal position, as viewed from front to back, they are represented by the lines marked R V, the ends (R R R) being removed to a greater distance from the back-bone, V V. In this case the distance from the front to the back of the chest is increased, or, in other words, the cavity of the chest is enlarged antero-posteriorly.

But simultaneously with the lateral and antero-posterior enlargement of the chest the diaphragm (see Fig. 31), which forms its floor, descends, thus increasing its vertical height; hence all three dimensions of the chest are simultaneously increased. The air, therefore, forced by its external pressure, rushes in to fill the additional space thus obtained.

Popular opinion, transposing cause and effect, erroneously attributes the enlargement of the chest to the inrush of the air, whereas the enlargement of the chest is the cause of the influx of the air which constitutes inspiration.

These movements, with the consequent thoracic enlargements, may readily be observed by placing the hands on the sides and on the front and back of the chest while breathing. They very much resemble those of a pair of bellows: when the sides of the bellows are separated, air rushes in; this corresponds with the process of inspiration: when they are pressed together, the air is forced out; this corresponds with expiration.

The following simple calculation will show that a small increase in the respective dimensions of the chest will produce a considerable increase in its cubical capacity:—Let it be supposed that the length, breadth, and height of a cubical box 6 inches in diameter were increased 1-3rd, then the ratio of the cubical capacity of the former to the latter would be as $6 \times 6 \times 6$ is to $8 \times 8 \times 8$, or as 216 c. i. are to 512 c. i.

Expiration, or the expulsion of the air from the lungs, is effected by the compression of the lungs, caused by the closing in of the diaphragm and walls of the chest. The diaphragm relaxes and is pushed up by the abdominal viscera, which are pressed in by the contraction of the muscles of the abdomen; the ribs and sternum fall forwards and inwards under the influence of gravity and the elasticity of the costal cartilages and ligaments. The internal intercostal and the abdominal muscles also assist in this movement. Probably also the organic muscular fibre in the walls of the cells, by its contractibility, assists in the expulsion of the air from the lung sacs.

Muscles of Respiration.—The principal muscles of ordinary inspiration are the external intercostals, a portion of the internal intercostals, the levatores costarum, a portion of the triangulis sterni, and the diaphragm. In forced inspiration all the muscles of the back and neck which act upon the ribs and sternum

assist, as the serratus, latissimus dorsi, pectorals, and sterno-mastoid.

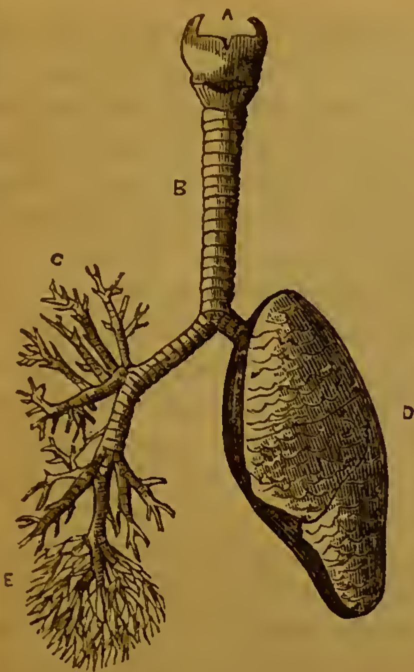
The principal muscles of ordinary expiration are a portion of the internal intercostals, the infra-costal and the abdominal muscles, and a portion of the triangulis sterni. In forced expiration the longissimus dorsi and the sacro-lumbalis also act.

Pectoral and Abdominal Respiration.—Respiration effected through the movements of the chest is described as pectoral or costo-superior; that effected through the movements of the diaphragm and the abdominal walls is termed abdominal respiration. The former predominates in females, as seen in the movements of the chest in singers; the latter in man.

The Pleura.—The interior of the thorax is lined by serous membranes, known as the pleuræ. Each pleura consists of a closed sac, a good idea of the arrangement of which is given by a woven night-cap, closed at both ends, or by a long silken purse. One portion of this sac is attached by its outside to the inside wall of the thorax, the other portion is reflected so as to form an internal sac by which the lung is invested.

The Structure of the Lungs.—The lungs (see Figs. 6, 30, and 34) occupy the greater part of the cavity of the chest. They consist of two large conical, spongy, elastic organs, which contain millions of little cavities or air-cells, the scheme of their structure being the mutual exposure of the largest surfaces of air and blood to each other.

The right lung comprises three, the left two lobes. Each lung consists of an immense multiplication of minute air-sacs, connected with a very complex system of air-tubes. It also contains a very elaborate system of capillaries, by which the blood is distributed over the surface of the air-cells, together



A. Larynx.
B. Trachea, showing cartilaginous rings.
C. Bronchial tubes, the soft parts of the right lung being dissected away to show air-tubes.
D. Left lung.
E. Ultimate bronchial tubes.

Fig. 34.—Trachea and Lungs.

with other larger bloodvessels for conveying the blood to and from the lungs.

All these various parts are held together by means of areolar tissue. The lungs are supplied with lymphatics and branches from the pneumogastric nerve.

The Larynx, or voice-box, at the top of the trachea, is fully described in the section on the "Organs of the Voice."

The Trachea (Gr., *trachus*, rough), or windpipe, is the principal air-tube of the lungs. It divides at its lower end into two smaller air-tubes, termed bronchi, one of which passes to each lung; its upper end terminates in the larynx, which is situated near the base of the tongue, at the back of the mouth. (See Figs. 6 and 35.) It is about four inches long and three quarters of an inch in diameter, and presents a rough, uneven surface, from which it derives its name, and which

may be felt by rubbing the finger against the front of the throat. It consists of an external tube formed of fibrous membrane, supported and strengthened on its front and sides by 16 to 20 imperfect cartilaginous (gristly) rings (the hinder third being wanting). The absence of the cartilage from the posterior parts of the rings permits of the flexibility necessary for the free passage of the food during the act of deglutition.

But for these cartilaginous rings a very slight pressure, even bending the neck, would close the windpipe and produce suffocation. The back of these rings is completed by a white, fibrous, tough, inelastic membrane, termed the perichondrium, which also invests the surface of the rings.

The inside of the trachea is lined with mucous membrane, covered with ciliated epithelium. Probably these cilia move in the direction of the glottis. The motion of these cilia, as observed under the microscope, somewhat resembles the waving of a corn-field in a steady breeze. One function of the cilia is the removal and extrusion of the dust and other mechanical impurities sucked in with the air during respiration, which would otherwise pass into and accumulate in the air-cells and produce inflammatory disease. The cilia receive the dust and pass it upwards till it reaches the back of the mouth. Their principal function is, however, the removal upwards of the mucus, which is always forming on the surface of the air-tubes, and which would otherwise gravitate into the air-cells.

Between the external fibrous and the internal mucous membrane of the trachea is a sheet of transverse unstriped muscular fibre. This muscle, termed the trachealis muscle, helps to complete the circle of the cartilaginous rings, and by its contraction alters the diameter of the tube.

Bronchi and Bronchial Tubes.—The trachea divides, at its lower extremity, into two bronchi; these again into other smaller tubes, termed bronchial tubes. These tubes are described as secondary, tertiary, and terminal bronchia. The terminal or ultimate bronchial tubes open into lung-sacs, or infundibulæ, or, as they are sometimes indefinitely termed, lobules.

The larger bronchial tubes have a similar structure to the trachea; the cartilaginous rings, however, differ from those of the trachea in being entire or complete rings. They are lined with ciliated epithelium.

The smaller bronchial tubes do not contain any cartilaginous rings, and are exceedingly delicate in their structure. They are about 1-70th of an inch in diameter. The function of the trachea and bronchial tubes is to distribute air to the air-cells. Inflammation of the mucous membrane lining these tubes is termed bronchitis.

The Lung-Sacs and Air-Cells.—The lung-sacs, or infundibulæ, as they are sometimes termed, are small, irregular, funnel-shaped sacs or pouches. They are attached to the terminal bronchial tubes. Their

Terminal air-vesicles of the human lung, hanging to a branch of the bronchi as berries hang to their stalk.

Fig 35.—Lung-Sacs and Air-Cells.

sides are everywhere honeycombed with minute cells —the air-cells, of which it is said there are as many as 18,000 in the walls of one lung-sac. It has been cal-

culated that the human lungs contain 600 millions of these air-cells.

It has been estimated that the lungs expose a surface of 1,400 square feet to the atmosphere.

Nerves of Respiration.—The lungs and air-tubes are chiefly supplied by nerves derived from the sympathetic and pneumogastric nerve. The diaphragm receives the phrenic nerve, from which it derives its power of motion.

Quantity of Air Respired.—Ventilation.—An adult breathes about eighteen times per minute, or about 9,000,000 times in each year. The total quantity of air contained in the lungs of an average man is about 250 cubic inches; the quantity changed or taken in by an ordinary inspiration is about 20 to 25 cubic inches. A man who, when naked, could take in 190 cubic inches by a forced inspiration, could, when dressed in his ordinary clothes, only inspire 130 cubic inches. About 375 cubic feet of air are respired daily, or about 150,000 cubic feet per annum. In every workshop or sleeping-room 800 cubic feet of space should be given each person, and the air in this space should be changed by ventilation at least twice each hour. Tight dress, sleeping with the head under the bedclothes, or in a cramped position, seriously lessen the growth and vigour of young people by impeding respiration.

Why the Air passes into the Lungs, and **not** into the **Cavity of the Thorax.**—Let A (Fig. 36) represent a glass cylinder, C a tube open at both ends fitted airtight into the cylinder, B a bladder tied to the outside of the tube, and D a moveable airtight piston fitting into the lower part of the cylinder. When the piston D is lowered, a partial vacuum is produced; the air therefore rushes through the open tube into and inflates the bladder; when the piston is raised, the in-

ternal capacity of the cylinder is reduced, the included air condensed, and the sides of the bladder driven in by its pressure, the contents of the bladder being expelled through the open tube, and the bladder itself entirely collapsing. If A be supposed to represent the thorax, B the lungs, C the trachea, and D the diaphragm, the action just described is very similar to what takes place in the process of breathing. This experiment may be made more interesting by substituting the lungs and windpipe of a sheep for the glass tube and bladder.

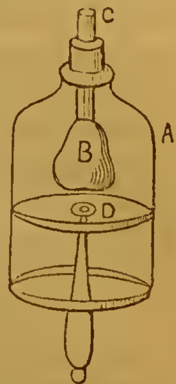


Fig. 36.

Asphyxia (Gr., *a*, not, and *sphugo*, I beat), or apnœa (Gr., *a*, not, and *pneo*, I breathe), is the cessation of breathing. Unless purely temporary, it always results in death. It may be caused by spasm of the glottis or the muscles of respiration, by breathing poisonous or irritating gases, by the withholding of the nervous influence through apoplexy, paralysis, the section of the pneumogastric nerve, pressure on that nerve (as in dislocation of the neck), the brain's becoming charged with venous blood, obstruction of the mouth or the air-passages.

Drowning, strangulation, and suffocation, whether caused by choke-damp or the carbonic acid of a ship's hold, produce death by asphyxia. Bronchitis and inflammation of the lungs usually produce death by obstructing the air-passages with phlegm : these diseases are therefore doubly dangerous in very young children, who have neither the sense nor the power to relieve themselves by coughing.

Artificial Respiration.—Several methods of restoring respiration in cases of drowning have been

devised; one consists in holding the two arms by the elbows and working them up and down like two pump-handles, the patient being placed on his back, his head inclined upwards, and his tongue kept down to leave the respiratory tract open. In this process about 44 cubic inches of air are alternately inhaled and expelled by the changes produced in the internal capacity of the chest. Care should be taken that the patient be kept warm.

ANIMAL HEAT.

Animal heat is chiefly developed by the combustion of the carbon, hydrogen, sulphur, and phosphorus of the food and tissues consequent on the process of respiration; but it is regulated by the action of the skin through the medium of the perspiration, which carries off the excess in the form of latent heat, so that a man may even bear the heat of a furnace with comparative impunity.

The temperature of arterial blood is about 100° F.; that of venous blood about 98° F. When the body falls much below this temperature death supervenes. During starvation the temperature of the body falls; during fever it sometimes rises to 107° or even 110° F.

It has been estimated that the amount of heat generated in the body of a man in 24 hours would raise the temperature of 6 gallons of water (about 60 lbs.) from 32° to 212° F.

NUTRITION AND REPAIR.

Nutrition is the process by which the plastic elements of the liquor sanguinis are built up into the tissues. Nutrition is the antagonist of decay: in infancy and youth it exceeds decay and determines growth; in middle age it balances decay; but during

old age decay exceeds nutrition, and gradually ruins and brings down the fabric, its complete and final victory culminating in death.

Conditions of Healthy Nutrition.

(1.) A healthy quality of the blood.
(2.) A proper quantity of blood in the part.
(3.) A certain influence of the nervous system. In some cases, where a nerve is injured or destroyed, the part not only wastes, but ulcerates away.
Feelings of hope and confidence are highly favourable to the cure of disease, while depression and foreboding of evil not only aggravate it, but frequently produce fatal results.
(4.) A healthy state of the part to be nourished.

Repair of Injuries.—All animals possess a greater or less power of repairing injuries or restoring lost members; the latter power is possessed to any considerable extent by the lower animals only. In the case of a sharp, incised, clean wound, if the opposite sides be brought close together, they will frequently heal with great rapidity by mere adhesion, and without the intervention of any appreciable quantity of lymph or blood; this, which is the most satisfactory to the surgeon, is described as immediate union.

When the parts are not brought properly together, or slight inflammation sets in, a portion of the liquor sanguinis, known to the surgeon as plastic or coagulable lymph, oozes from the adjacent bloodvessels, becomes organized, and joins the surfaces together by adhesion; this is known as healing by the first intention, or by "adhesive inflammation."

Repair of a Broken Bone.—When a bone is fractured, more or less blood from the ruptured vessels of the bone and its periosteum effuses into the wound and forms a coagulum. Shortly afterwards, a semi-transparent organizable fluid (the plastic lymph) exudes into the coagulum and solidifies, joining the ends of

the bone together; also, if the bone is tubular, forming a plug, filling the portion of the medullary canal immediately adjacent to the fracture, and likewise forming an external ring, encasing the exterior of the fracture. Earthy matter is deposited in this substance until it forms a hard, spongy, bony mass, termed by Dupuytren the provisional callus. This is afterwards gradually removed by the absorbents, Haversian canals being developed, and true bony tissue, forming the permanent callus, being deposited.

SECRETION AND EXCRETION.

Structure of Glands.

All animals except the lowest classes are endowed with special organs, as the salivary glands, and the liver, whose duty it is to separate, elaborate, or secrete from the blood certain fluids or substances useful to the body. They are also endowed with other organs, whose duty it is to separate or excrete from the blood certain useless or injurious substances. The former are termed organs of secretion; the latter of excretion.

Excretion and Secretion. (See page 8.)

Organs of Secretion.—The principal glands, or organs of secretion, are the salivary glands, the liver, pancreas, and the lachrymal and mammary glands.

Plan of Structure.—All glands are formed on the same principle. They consist mainly of a secreting membrane and a network of capillaries.

The secreting membrane consists of basement membrane covered by a layer of epithelial cells. The basement membrane is homogeneous and structureless. The epithelial layer varies in thickness, and, to a certain extent, in the size and form of the cells of which it is composed.

The process of secretion is supposed to be effected through the agency of these cells.

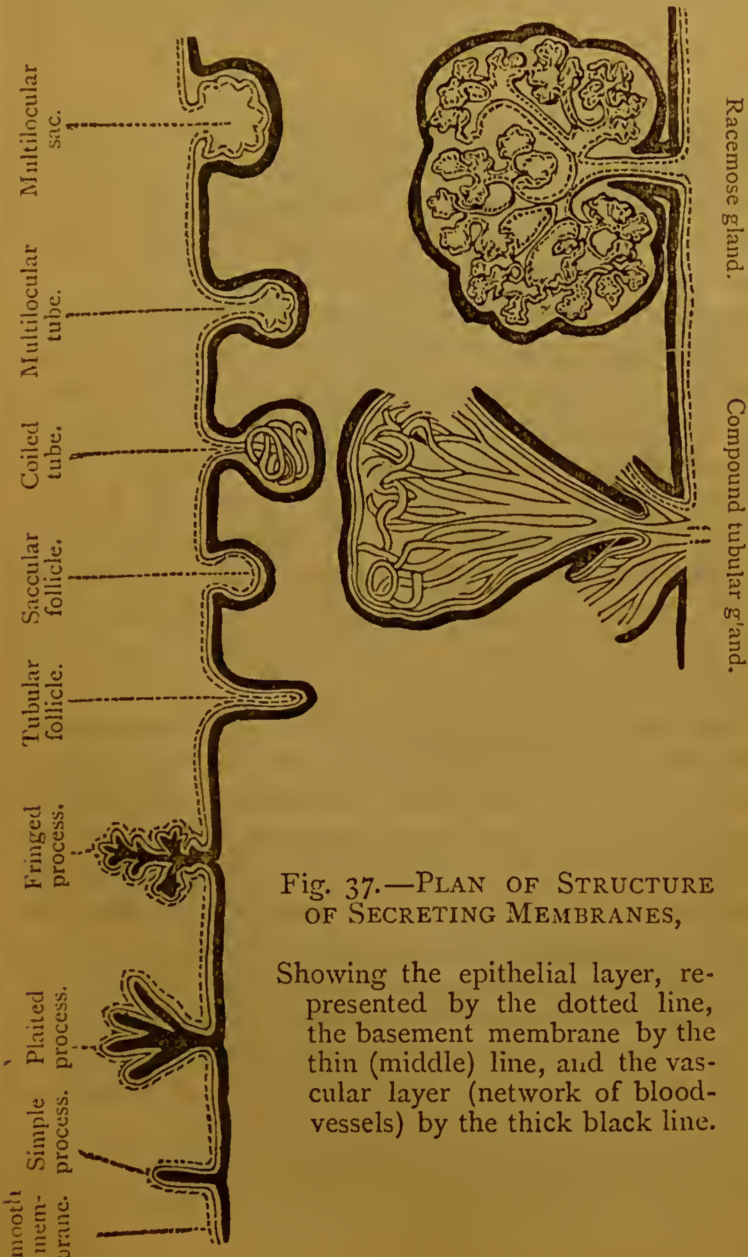


Fig. 37.—Plan of Structure of Secreting Membranes,

Showing the epithelial layer, represented by the dotted line, the basement membrane by the thin (middle) line, and the vascular layer (network of blood-vessels) by the thick black line.

THE LIVER, GALL-BLADDER, AND THE BILE.

Appearance, Size, and Function.—The liver is a large reddish-brown organ. It is the largest gland in the body, is about 13 inches long and 7 inches broad, measures about 90 cubic inches, and weighs 3 to 5 lbs. It secretes 3 to 5 lbs. of bile per day.

Situation.—The liver is situated in the upper part of the abdomen, immediately under the right half of the diaphragm, into the concavity of which it is fitted, and to which it is attached. It overlies and rests on a portion of the pyloric pouch of the stomach, upper part of the colon, and the kidney. (See Fig. 8.)

Coats or Investments of the Liver.—The greater portion of the surface of the liver is covered by the peritoneum. It is also completely invested with a fibrous coat of its own. This coat enters and lines the portal canals.

Structure of the Liver.—The liver consists of five lobes—a right and a left lobe, and three smaller.

The compact reddish-brown substance of which the mass of the liver is composed consists of a secreting and a vascular structure. The secreting structure consists of an immense number of minute granules, or nucleated polyhedral cells, of a brownish-yellow colour, held together by areolar tissue. (See Fig. 39.) These, termed hepatic cells, are 1-1,600th to 1-800th inch in diameter; they are clustered in lobules, termed Malpighian lobules, or acini, of irregular form, about the size of a pin's head. These lobules or acini are arranged upon the ultimate branches of the hepatic veins like leaves upon a tree, thus giving to a vertical

section of the lobules the peculiar arborescent appearance shown in the diagram. (See Fig. 41.) The hepatic cells, which form its true parenchyma, compose

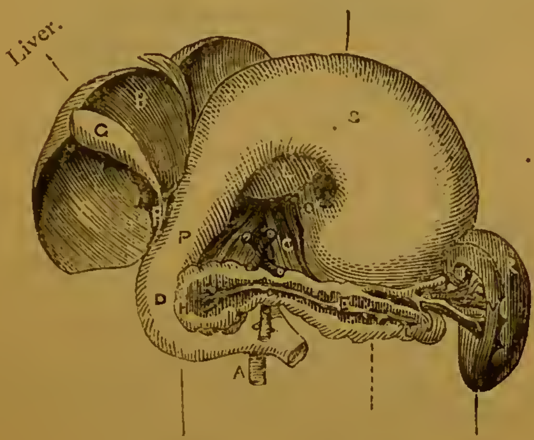


Fig. 39.—STOMACH, LIVER, AND PANCREAS.

The liver and stomach are turned up to display the duodenum, pancreas, spleen, and their ducts and vessels. The pancreatic duct traverses the whole length of the gland.

B. The under surface of the liver.
G. Gall-bladder.
F. Common bile-duct, formed by the union of the cystic duct leading from the gall-bladder and the hepatic duct from the liver.
O. The cardiac end of the stomach, proceeding from the œsophagus.
S. The under surface of the stomach.
P. Pyloric end of the stomach.
D. Duodenum.
H. Head of pancreas.
T. Tail ,, ,,
I. The body of the pancreas, the substance of which is removed in front so as to show the pancreatic duct, E, and its ramifications.
R. The spleen.
V. The hilus at which the bloodvessels enter.
C. The crura of the diaphragm.
A. The aorta.
L. Part of under surface of left lobe of liver.

the great mass of the liver, and entirely fill up the meshes and interstices of its vascular network, being

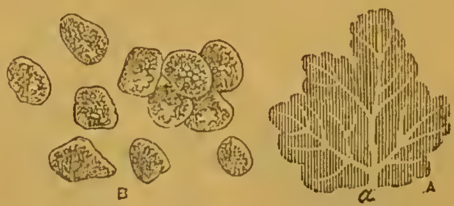


Fig. 40.—STRUCTURE OF HUMAN LIVER.

A *a*. Branches of hepatic vein (intralobular). The shaded portion shows four lobules attached to the branches of the hepatic vein like leaves to the branches of a tree. This diagram represents the lobules twice their natural size.
B. Hepatic or biliary cells, the nucleated cells of which the lobules are composed, magnified 200 times.

moulded about the walls of the capillaries and the hepatic ducts.

Fig. 41.—HEPATIC VEIN AND LOBULES.

Vertical section of human liver, showing—
A. Hepatic (intralobular) vein, trunk with tributary twigs.
B B B. Biliary lobules attached, like leaves to the terminal branches of a tree.

The lobules are separated (see Figs 41 and 42) from each other by the plexuses of the portal veins and hepatic ducts by which they are surrounded. It is uncertain whether they have distinct capsules.

Bloodvessels of Liver.—The liver is supplied with blood by the portal vein and hepatic artery. The larger branches of these vessels, together with the larger hepatic ducts, are contained within common sheaths of connective tissue termed portal canals.

Portal Canal.—The portal canal is the common sheath of areolar and elastic tissue which ramifies through the substance of the liver, affording a common passage for the ramifications of the portal vein, the hepatic artery, and the hepatic duct. It is lined by the membrane termed Glisson's capsule.

Portal Vein.—The portal vein, or the vena porta, is a large vein which enters the porta or gateway of the liver. It is formed by the junction of the veins from the stomach, intestines, pancreas, and spleen, viz., the gastric, the superior and inferior mesenteric, and the splenic veins. The impure venous blood is collected from the organs mentioned, and instead of being conveyed directly to the vena cava, like the rest of the venous blood, is passed through the liver, thus affording the material from which the bile is elaborated.

The more minute branches of the portal veins traverse the interlobular spaces, surround the lobules, and give off their ultimate ramifications, the portal capillaries, which pass into the interior of the lobules, and terminate in the commencing twigs (capillaries) of the hepatic veins. The capillaries of the portal vein thus hold the same relation to the capillaries of the hepatic

vein that the general arterial capillaries hold to the venous capillaries.

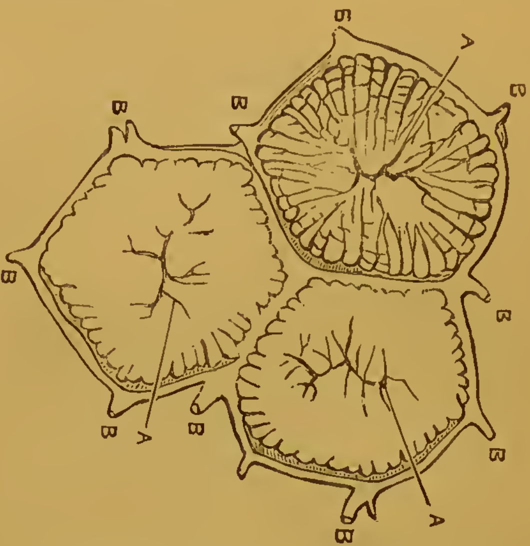


Fig. 42.—TRANSVERSE SECTION OF THREE LOBULES OF LIVER,

Showing the two principal systems of bloodvessels in the liver.

A A A. Hepatic veins, the intralobular veins.
B B B. Network of portal veins, the interlobular, which surround the lobules, giving off the portal capillaries which pass between the biliary cells to the centres of the lobules, where they join the rootlets of the hepatic veins.

Function of Portal Vein.—The portal vein supplies the impure blood from which the liver secretes the bile. This has been proved by tying the portal vein just before its entrance into the liver, in which case no bile was secreted. No such result follows ligature of the hepatic artery.

The Hepatic Artery supplies the blood by which the liver is nourished.

Hepatic Ducts.—The hepatic or biliary ducts probably commence among the hepatic cells, pass off at the surface of the lobules, and join with others to form larger branches, which finally unite to form the

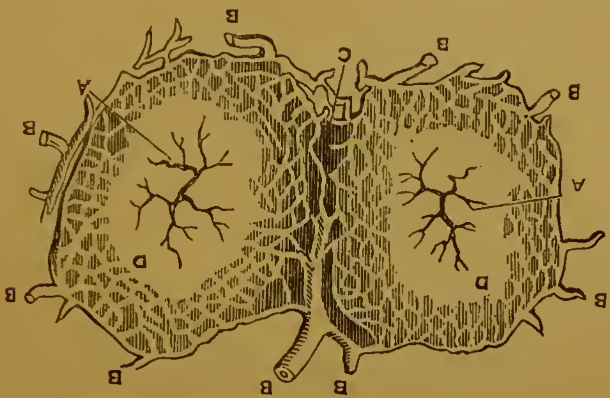


Fig. 43.—TRANSVERSE SECTION OF TWO LOBULES OF THE HUMAN LIVER.

Showing interlobular network of biliary or hepatic ducts surrounding lobules, and sending off branches between the biliary cells towards the centres of the lobules.

A A. Branches of hepatic (intralobular) veins.
B B. Branches of hepatic ducts surrounding lobules.
C. Interlobular spaces.
D. Substance of lobule.

hepatic duct. The actual mode in which the biliary ducts commence, or their exact relation to the hepatic cells, has not yet been satisfactorily determined. The hepatic duct, after leaving the liver, joins the cystic duct, at a very acute angle (see 12, Fig. 7) and forms the common bile-duct (ductus communis choledochus), (see Fig. 39), which is about three inches long. The common bile-duct enters the duodenum along with the

pancreatic duct at a very acute angle, passing obliquely between its coats for a distance of three quarters of an inch. At their commencements the hepatic ducts do not exceed 1-5,000th to 1-4,000th of an inch in diameter; they are lined with glandular epithelium; in the larger ducts it becomes tesselated.

The Lobules of the Liver, which are small, somewhat conically-shaped, granular bodies, 1-20th to 1-10th of an inch in diameter, or about the size of a millet seed, consist of a number of hepatic cells held together by the capillaries, and possibly by basement membrane. The spaces between the lobules are termed interlobular spaces or canals, and the portal viens which surround the lobules, and occupy these spaces, are termed interlobular veins. (See Figs. 40 to 43.) The interior or central portion of each lobule is occupied by a capillary plexus of the hepatic vein. The hepatic veins are therefore termed intralobular veins. The hepatic veins, occupying the centre of the lobules, pass at right angles from the axis of the lobules into larger branches of the hepatic veins at the base of the lobules; these veins are therefore termed sublobular veins.

The Gall-Bladder is a small pear-shaped sac, situated under the right lobe of the liver. (See Fig. 39.) It is connected with the hepatic duct by the cystic duct, which is about one inch and a half long, and about the diameter of a crowquill. The human gall-bladder is capable of holding from one to two ounces of fluid; its principal function is to divert and retain the bile from the intestine during the period when digestion is not proceeding. The secretion of the bile is continuous, and not remittent, like that of the other digestive juices, but it is secreted most rapidly a few hours after a meal.

The Bile is a transparent, greenish yellow, somewhat viscid alkaline liquid; it has a disagreeable odour, and a peculiar, most nauseous, and bitter taste. Its alkaline properties enable it to neutralize the acidity of the chyme. It froths when shaken, and has a soapy feel. Ox-gall is used for cleaning carpets, and also as a powerful purging medicine. Its principal constituents are two fatty acids, taurocholic and glycocholic acids, which are combined with soda, forming two soaps, biliary pigment, and a small quantity of cholesterin (a peculiar fat), which is probably held in solution by taurocholic acid. When the cholesterin is in excess it gives rise to the formation of gall-stones, which sometimes, by stopping the passage of the hepatic duct, prevent the bile's escaping from the liver into the duodenum, in which case it is absorbed directly from the liver into the blood, producing the disease known as jaundice. The peculiar yellow appearance of the skin, from which the disease takes its name, is due to the deposition of the colouring matter of the bile in the substance of the skin. The organic constituents of the bile consist principally of hydro-carbons.

The Functions of the Bile are not very thoroughly understood, but it is now generally admitted by physiologists that among others it performs the following offices :—(1) it assists in the formation of the chyle; (2) it separates the excrementitious and useless parts from the nutritious parts of the chyme; (3) it probably aids the absorption of the fat, moistening the villi of the intestines, and thus rendering them more penetrable by the neutral fats (by osmosis); (4) it stimulates the peristaltic action of the intestines, its presence in excess producing diarrhœa.

The Functions of the Liver are but imperfectly known, some of them being still subjects of discussion among physiologists; the following are, however, among those best determined:—(1) it aids digestion by the secretion of the bile; (2) it purifies the blood, removing injurious substances from it, the bile being principally an excrementitious substance possessing well-marked poisonous properties, and producing death by coma or insensibility when a sufficient quantity of it finds its way into the brain; (3) it elaborates two heat-giving substances, viz., fat and a glycogenic (sugar-forming) substance, which is burnt off in the pulmonary circulation as a respiratory fuel; (4) it promotes, through the stimulus of the bile, the healthy peristaltic action of the intestines; (5) Dr. Carpenter and other modern physiologists are also of opinion that it exercises an assimilative or elaborative action on the freshly absorbed albuminous, saccharine, and other elements of the food.

Glycogenic Function of the Liver.—Healthy blood drawn from the portal vein and the hepatic artery, and which has therefore not passed through the liver, yields no trace of glycogenic substance, while it is easily detected in blood drawn, after traversing the liver, from the hepatic vein, thus proving it to be formed during the passage of the blood through the liver.

SALIVARY GLANDS.

The Salivary Glands are described as conglomerate, racemose, vesicular glands (L., *racemus*, a bunch of grapes): they consist of numerous lobes; these are made up of lobules, the whole being connected together by ducts, bloodvessels, and areolar

tissue. Each lobule consists of a collection of closed sacs, vesicles (see Fig. 44), or acini (about 1-1,200th

Fig. 44. — PORTION OF SALIVARY GLAND INJECTED WITH MERCURY,

Showing—1. Bunches of grape-like vesicles.
2. Salivary ducts, forming branching tubes.

inch in diameter), which open into a primary branch or rootlet of an excretory duct; these ducts unite to form the larger ducts by which the saliva is poured into the mouth. The walls of the lobules consist of fine basement membrane, covered externally by a dense plexus or network of capillaries, and internally by a layer of epithelium. The lobes and lobules are invested more or less completely in a capsule of areolar tissue. The **nerves** of the salivary glands are derived from the gustatory or 5th cranial nerve.

PANCREAS AND PANCREATIC JUICE.

Appearance, Size, and Situation of the Pancreas.—The pancreas (from Gr., *pan*, all, and *kreas*, flesh), or sweetbread, is a soft, milky, or pinkish white tongue or hammer-shaped gland, about 7 inches long, 3 inches broad, and 1 to 2 inches thick; it contains about 5 cubic inches, and weighs from 3 to 5 oz.

It probably secretes about half a pint per day of a fluid termed the pancreatic juice, which closely resembles the saliva.

It is situated in the abdomen, at the back of the stomach, immediately in front of the aorta and vena cava. Its head or larger end is placed in the concavity of the duodenum (see Fig. 39); its tail, or lesser extremity, which tapers off considerably, is in contact with the spleen. It is retained in its place by areolar tissue, and by folds of the peritoneum.

The Structure of the Pancreas.—The pancreas has no distinct capsule, but it is invested with an irregular covering of condensed areolar tissue. Septa, or partitions from the external covering, dip into the substance of the gland, and divide it into lobes and lobules.

Pancreatic Duct.—The main pancreatic duct (see Fig. 39) commences at the left or smaller end (the tail) of the pancreas, traverses the gland from left to right, receiving numerous tributaries on its way, and leaves the head of the pancreas, entering the duodenum with the common bile duct (see Fig. 7).

The Pancreatic Juice is a clear, colourless, structureless, viscid liquid, very much resembling saliva in appearance and general properties. Its specific gravity is about 1·010; it contains about 10 per cent. solid matter.

It is alkaline, but it differs from the saliva. It acts even more powerfully upon starch (converting it into sugar) than saliva. It purifies rapidly, by which fact it is distinguished from pepsin and ptyalin. It converts fat into a complete emulsion, and thus, by effecting its minute subdivision, promotes its absorption by the villi of the intestines in the formation of chyle. It is said, when the pancreatic duct is obstructed by

disease, or diverted from the intestine, that the fat passes off unchanged in the stools. It is coagulated by heat, alcohol, nitric acid, and some salts. It is said to contain a peculiar animal principle termed pancreatin, or phymatin. Whether, and if so how, it acts on the albuminous portions of the food, is still a subject of discussion among physiologists.

Functions of the Pancreas.—The pancreas has been called the abdominal salivary gland; it aids digestion—1, by secreting a juice whose special power is to digest fatty matters; 2, it also aids digestion of those starchy substances which have not been sufficiently acted upon by the saliva, converts them into sugar, and thus rendering them soluble and capable of absorption; it likewise promotes osmosis by its liquidity.

DUCTLESS GLANDS.

The Spleen, Suprarenal Capsules, Thyroid Gland, and Thymus Gland.

The Spleen.

Appearance, Size, and Situation of the Spleen.—The spleen (the milt of the lower animals) is a soft, somewhat crescent-shaped body, of a dark purplish colour. Its interior or concave surface is broken by a hilus or fissure, through which the nerves and vessels pass to and from the spleen. It varies very much in size at different periods of the digestive process. (See R, Fig. 39.)

It is situated on the left side of the abdomen, the left hypochondriac region near the tail of the pancreas, immediately behind the larger (cardiac) end of the stomach, to which its concave surface is attached. Its upper convex surface is fitted to the diaphragm, which

separates it from the 9th, 10th, and 11th ribs; its lower end lies over the left kidney.

Malpighian Corpuscles.—The splenic or Malpighian corpuscles are little semi-obaque, somewhat gelatinous, oval bodies, about 1-40th of an inch in diameter. (See Fig. 45.) They are situated upon the

Fig. 45.—PORTION OF SPLEEN,

Showing—1. Splenic corpuscle, or Malpighian body (the oval body in the centre of the figure.)
2. Miuute arteries.
3. The trabecular network (represented by the finer lines).

ends of the arterial twigs, each of which, after bifurcation, sends out a network of capillaries which embraces or surround the Malpighian corpuscles.

Functions of the Spleen.—Though the structure of the spleen is very peculiar, differing from that of all the other organs in the body, and has been well studied by Gray, Huxley, and other eminent physiolo-

gists, yet its function may be said to be quite undetermined. It probably acts—1, as a receptacle for and a regulator of the quantity of blood used in digestion, relieving the overcharged bloodvessels of the stomach, liver, and other adjacent organs ; 2, it probably exercises some influence on the cell formations of the blood, the red corpuscles being said to be more numerous after the blood has passed through this organ. It is said that animals from whom it has been extirpated do not seem to suffer any permanent injury. This most probably arises from its function being taken up by other organs. The ancients described the spleen as the seat of melancholy, vexation, and ill-humour ; hence the origin of the term splenetic.

The Thyroid Body is situated at the upper part of the trachea on each side of the base of the larynx, and is one of the simplest of the vascular glands. (See Fig 6.) It is of a brownish red colour, and comprises two lateral lobes, connected by a narrow portion, termed the isthmus, which extends across the front of the third or fourth ring of the trachea. The thyroid gland has no excretory ducts, and its function is quite unknown. It is the seat of the hideous disease known as goitre, Derbyshire neck, and bronchocele, so common in Switzerland.

The Thymus Gland is a pinkish grey organ, which is situated at the base of the neck and upper part of the thorax. It lies behind the sternum (breast bone), and rests on the aortic arch. Its function is unknown.

THE KIDNEYS AND THEIR EXCRETION.

Appearance, Situation. and Size of the Kidneys.—The kidneys are two dark, reddish brown, bent, oval-shaped bodies, situated in the loins, at the

back of the cavity of the abdomen one on each side of the lowest dorsal and upper lumbar vertebræ. They lie outside and behind the peritoneum, the left kidney lying behind the larger end of the stomach. They are surrounded by much loose areolar tissue and fat, which give them much additional support and protection, and help to keep up their temperature; they are retained

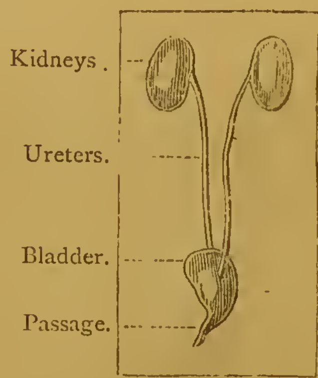


Fig. 46.—Plan of Urinary Organs.

in their respective positions chiefly by the bloodvessels, nerves and ureters.

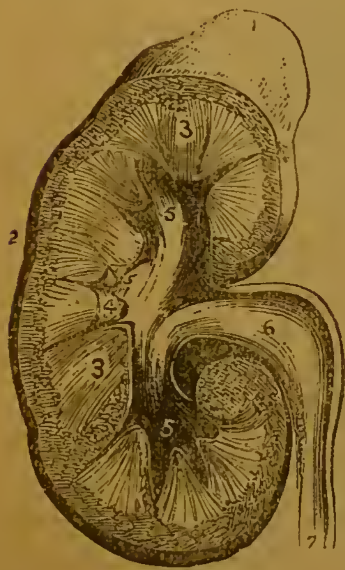
The internal or concave border of the kidney is penetrated by a notch or fissure, termed the hilus. This opening affords entrance to the renal artery and the nerves, and exit to the ureter, renal vein, and absorbents.

The kidneys weigh about 5 ounces each, and are about 5 inches long, 2 inches wide, and 1 inch thick.

Structure of the Kidneys.—Each kidney is enclosed within its own proper fibrous coat or capsule, which is composed of fibro-areolar tissue. This investment passes in at the hilus and lines the sinus and infundibulæ, also affording sheaths to the nerves and

bloodvessels, and, according to some physiologists, forming the matrix of the kidney.

If a very thin longitudinal slice of the kidney be placed between two pieces of glass, and examined by a microscope of moderate power, two distinct structures, constituting the parenchyma of the kidney, may be observed, viz. :—



1. Suprarenal capsule.
2. Cortical or vascular portion of kidney.
3, 3. Medullary portion (tubuli uriniferi, forming Malpighian pyramids).
4, 4. Papillæ formed by apices of pyramids.
5, 5, 5. Three infundibulæ, or funnel-shaped branches of the sinus of kidney.
6. Pelvis.
7. Ureter.

Fig. 47.—Section of Kidney and Suprarenal Capsule.

1. The **cortical** (outer) layer, about one-sixth of an inch in thickness, which consists of a soft granular, and vascular substance, studded with dark red spots, the Malpighian corpuscles. This substance also dips into the interior or medullary portion of the kidney.

2. The **medullary** or interior portion, distinguished by its striated appearance.

The Cortical structure forms about three-fourths of the substance of the kidney, and consists chiefly of convoluted tubuli, uriniferi, Malpighian corpuscles (see

(Fig. 48), bloodvessels, nerves, and lymphatics, held together by areolar tissue and granular substance.

Fig. 48.—Plan of Circulation in Kidney.

The Medullary or Inner Structure of the Kidney is paler and firmer than the cortical portion, and is striated even to the naked eye. It consists chiefly of straight tubuli uriniferi. These tubuli are collected into conical masses termed Malpighian pyramids. There are eight to fifteen pyramids (see Fig. 47) in each kidney. The bases of the pyramids are turned to the surface of the gland, their apices being consequently turned towards the centre of the organ.

The Malpighian Bodies, or the **Glomeruli** of the kidneys, are little rounded bodies about 1-120th of an inch in diameter. They consist of minute arterial tufts encased in delicate transparent capsules.

A little artery, termed the afferent vessel, or vas inferens, passes through the wall of the saccule or dilatation in the uriniferous tubule; it then splits up into four or five smaller arteries, which form little arterial tufts (the Malpighian corpuscles); the ultimate branches of the artery unite to form the vein termed the efferent vessel, or vas efferens, which emerges from the corpuscle in close proximity to the efferent artery.

The Renal Arteries (see Fig. 26) enter the kidneys at the hilum, after dividing into four or five branches along with the renal veins and ureters. They are exceedingly large for the size of the organs they supply. It has been estimated, from the size of the arteries in relation to those of other parts of the body, that, in proportion to their weight, 200 times as much blood passes through the kidneys, as circulates through the rest of the body generally.

The Renal Veins commence in the capillary network of the kidney, and after repeated junction and anastomosis, terminate in one efferent trunk termed the renal vein.

The Ureters are two very dilatable tubes, each of which is about eighteen inches long and about the diameter of an ordinary quill. Their function is to conduct the urine from the kidneys into the bladder; they penetrate the exterior wall at the base of the bladder, and after running very obliquely for about an inch, open into the interior by two slit-like apertures.

The Bladder is a hollow conical bag which receives the urine as it leaves the ureters (see Fig. 46). It, like the stomach, consists of four coats:—1, a serous external coat; 2, muscular; 3, a fibrous or submucous coat; 4, an internal mucous coat. It is so contractile that, when empty, it presents scarcely any internal cavity; yet, when distended, is capable of

holding 9 to 12 pints of liquid, in which case its walls become exceedingly thin and liable to fracture. If the bladder be ruptured or otherwise injured, so that any of the urine escapes into the adjacent tissues, death usually follows; urea, the principal constituent of the urine, being a powerful blood poison.

The Function of the Kidneys is the cleansing of the blood by the excretion of the urine. The urine is an aqueous solution of the dead or disintegrated muscle, nerve, or other tissue. It is the vehicle by which the effete, wasted, broken-up, nitrogenous matter of the tissues is eliminated from the system. The principal solid constituent of the urine is a nitrogenous substance termed urea. Professor Haughton states that the quantity of this substance daily excreted is greatly increased by brain work. He gives 400 grs. as the average quantity secreted daily by an ordinary labouring man, and 533 grs. as the quantity secreted by the hard-working student or professional man.

The importance of the thorough elimination of these effete nitrogenous products of the dead tissues is shown by the extent of the excreting surface which nature has provided for its removal. It has been estimated that the secreting surface of the tubuli of the kidneys is six times as extensive as that of the skin.

Urea, the principal organic constituent of urine, is a transparent, colourless, soluble, crystalline substance, which may be extracted from the urine by the action of nitric or oxalic acid; nitrate or oxalate of urea is thus formed, the urea of which may be easily separated by the addition of carbonate of lime or baryta. Urea is neutral to test-paper, but readily combines with most acids. Urea is not formed, but simply separated from the blood by the kidneys.

Uric or **Lithic Acid,** which is a purely excrementitious product, constitutes but a very small portion of human urine, but exists in considerable quantities in the urine of some of the lower animals, particularly in the solid urine of serpents, from which it is generally prepared. It is deposited in crystals when hydrochloric acid is added to the concentrated urine. When pure it is a white, crystalline, nearly insoluble acid powder. Hippuric acid displaces uric acid in the urine of the horse and cow.

When uric or lithic acid is in excess in the urine it tends to form gravel and stone or urinary calculi in the bladder. It also collects in the joints of gouty patients, forming, in combination with soda, concretions known as chalkstones.

Urea a Test of Work.—Not only is the quantity of urea and uric acid eliminated by the kidneys a test of the quantity of nitrogenous food daily required, but it is also a test of the amount of useful or dynamical work actually performed by the animal body.

Mechanical work (or 15 lbs. raised one mile)	= 136·5 grs.	of urea.
Mental work (or five hours' study)	= 217·0	,,
Vital work	= 297·0	,,
	650·5	,,

THE STRUCTURE AND FUNCTIONS OF THE SKIN AND ITS APPENDAGES.

The Skin forms the outer integument of the body. It covers the whole of its exterior, and with some slight modification, not materially affecting the plan of its structure, passes into its interior, and, in the form of mucous membrane, lines the whole of the alimentary canal. Upon the health and appearance

of the skin depends to a very great extent the beauty and comeliness of the human body.

Structure of the Skin.—The skin is a complex membrane consisting of three coats or layers:—

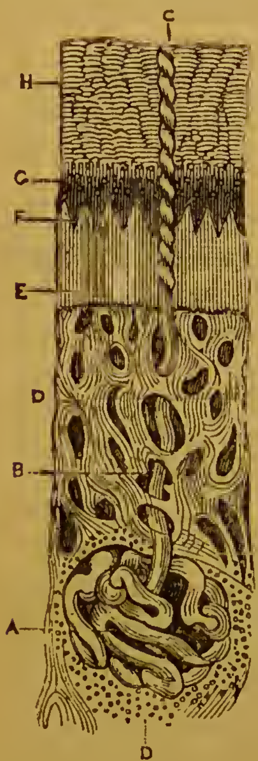


Fig. 49.—SECTION OF SKIN.

A. Sudoriparous gland.
B, C. ,, duct.
D. Subcutaneous cellular and adipose tissue.
E. Cutis.
F. Papillæ.
G. Rete mucosum.
H. Epidermis.

1, the cuticle, or outer layer; 2, the basement membrane; 3, the cutis, or true skin. It is very abundantly supplied with sudoriparous and sebaceous glands and ducts, and in many parts is extensively excavated with hair follicles.

The Cuticle, Epidermis, or Scarf-skin, forms the outer layer of the skin; it contains neither blood-vessels nor nerves, and is therefore quite insensible. This may be shown by passing a needle through it,

the process neither causing pain nor bleeding; it is this portion of the skin which is raised when a blister is formed. Its chief functions are—1, to protect the true skin from dirt and the action of the atmosphere; 2, to confine evaporation to the pores; 3, to lessen the sensitiveness of the true skin. Its importance in this latter respect is shown by the intense smarting which is excited when a hard or pointed object is brought into contact with any abraded portion of the skin.

Pores of the Skin.—The surface of the skin is penetrated by about 7,000,000 perspiration tubes or ducts, which open obliquely on the surface of the cuticle. The mouths of these tubes form the pores of the skin from which the perspiration exudes. If the surface of the skin be not frequently washed, these pores become obstructed, the process of excretion is partly arrested, and more or less of the dirt and poisonous organic matter is absorbed into the blood.

Rete Mucosum.—The colour of the skin of the negro and other races lies in the lower and newly formed layers of cells in the cuticle. These layers contain a number of pigment cells, which impart to the skin its distinctive colour. They were formerly imagined to constitute a distinct layer, which was termed the rete mucosum.

The Cutis, Dermis, Corium, or True Skin, lies immediately under the cuticle, the latter being everywhere moulded to it. It consists—1, of a compact layer of areolar tissue; 2, of a network of capillaries; 3, of a network of nervous fibrils; 4, of a network of lymphatics or absorbents; 5, of adipose (fat) tissue; 6, it is supposed to contain muscular fibre; 7, it contains millions of sudoriparous (sweat) glands; 8, it also contains sebaceous (oil) glands. The cutis is attached to the parts below by areolar tissue.

Nerves of the Skin.—The skin is abundantly supplied with nerves, the branches of which, like the capillaries, ramify through meshes in the areolar framework. They are distributed so extensively and closely through the skin that it is impossible to puncture the true skin without causing pain. Most of the nervous fibrils pass up to the surface of the true skin and terminate in little looped extremities, giving rise to the formation of papillæ.

Relative Sensibility of the Skin.—The skin in different parts of the body possesses different degrees of sensibility, those parts being most sensitive which are most abundantly supplied with nerves. The most sensitive parts in the surface of the body are the point of the tongue and centres of the lips; they are much more sensitive than the tips of the fingers. The relative sensibilities of the different parts of the skin may be proved by the following simple experiment:—Take a pair of drawing compasses, with their points slightly blunted, and apply them to different parts of the skin. The following table shows the respective distances at which the two points may be distinguished at the different parts. At less than the given distances the two points appear as though they form but one point:—

TABLE SHOWING SENSIBILITY OF SKIN.

Point of tongue . .	½ line.	Palm of hand . . .	5 lines.
Tip of finger . . .	1 ,,	Forehead	10 ,,
Red surface of lips .	2 lines.	Back of hand . . .	14 ,,
Tip of nose . . .	3 ,,	,, thigh . .	30 ,,

Papillæ of the Skin.—If the skin of the finger or the palm of the hand be carefully examined it will be observed to be marked with little curvilinear rows of elevation, separated from each other by intervening

furrows or grooves. The rows of elevation are formed by minute nerve loops previously referred to, projecting above the rest of the surface. The cuticle which lines their surface dips in between these rows of papillæ and gives rise to the groove marking referred to. The papillæ are most numerously distributed to the palms of the hands, the tips of the fingers, the lips, and the tongue. In the latter they have not the same regular arrangement that they have in the former.

Structure of the Papillæ.—When the cuticle is removed, the papillæ, as shown in the diagram, consist of a number of minute conical bodies. They are about 1-100th of an inch in height and 1-250th of an inch in diameter. They are composed of a central nerve loop fibril, and of a capillary vein and artery invested externally by the basement membrane. The papillæ really constitute a prolongation of the true skin into the substance of the cuticle. (See F, Fig. 49.)

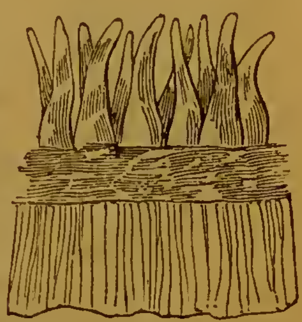


Fig. 50.—Dermis and Papillæ of Foot.

In addition to the parts just mentioned the papillæ of the most highly sensitive surfaces are found to contain a minute microscopic, hard, solid, oval body, termed the axile body, or tactile corpuscle. These bodies occupy the centre of the papillæ; they receive the end of the nervous fibrils, which, in some cases pass up their centres and terminate in their axes, but in some cases wind round their circumference. They very much resemble the Pacinian corpuscles in their structure.

Their function is not well understood; but they are supposed, as in the case of the otolithes in the ear, to render sensation more acute.

Fig. 51.—A Pacinian Corpuscle.

It has been calculated that upwards of 2,400 papillæ exist in one square inch of skin on the tips of the fingers.

The papillæ in some parts of the skin, as on the tongue, are not conical, but variously shaped.

The Skin a Respiratory Organ.—The skin absorbs oxygen and exhales carbonic acid gas. This may be proved by confining the human body in an oiled silk bag fastened round the neck. The residual air in the bag will be found, on careful analysis, to contain less than its ordinary proportion of oxygen, but a considerable excess of carbonic acid will be present.

It has been variously estimated, as the result of experiment, though apparently of no great accuracy, that the quantity of carbonic acid gas exhaled from the skin is 1-40th of that exhaled by the lungs. The importance of bathing and extreme cleanliness is therefore manifest.

The Perspiratory Function of the skin is its most important function. By means of this function the skin both purifies the blood and regulates the animal heat. It is effected by means of the sudoriparous glands to be presently described. Perspiration is always being exhaled from the skin in the state of invisible vapour that is termed invisible perspiration. This may be proved by bringing the hand or any part of the body into contact with a bright polished metallic surface, when its lustre will be immediately dimmed by the condensation of the invisible vapour passing from the skin.

The quantity of perspiration secreted daily varies with the health, the temperature and moisture of the air, the amount and degree of exercise, and the quantity of liquid drunk; also with the activity of the lungs and the kidneys, more especially the latter. The quantity of perspiration daily excreted by puddlers, glass-blowers, and furnace men is scarcely credible. According to Dr. Southwood Smith's experiments at the Phœnix Gas Works, certain gasmen employed at the furnace lost upwards of 5 lbs. in weight in the course of 70 minutes. The average daily quantity of insensible perspiration secreted is estimated at about 2 lbs. This contains about 140 grs. of solid matter. The solid matter does not increase in the same ratio as the liquid secreted. In summer the quantity of the perspiration excreted exceeds that of the urine; in winter, on the contrary, the quantity of urine exceeds that of the perspiration.

The importance of this excretion is shown by the fact that the presence of lactic acid in the blood is the probable immediate cause of rheumatism. It can always be detected in the blood of rheumatic patients. The following experiment also tends to show the relation of rheumatism to the presence of lactic acid:—Inject lactic acid into the veins of a dog or cat; in the course of a short time all the symptoms of severe rheumatic disease will set in, and if the animal be examined after death all the peculiar internal marks of the disease, especially those about the heart and joints, will be manifested.

During severe bodily labour much lactic acid is developed in the system. Damp or cold, acting upon the skin, tends to check its action, and therefore to favour the accumulation of lactic acid in the body; hence their influence in developing rheumatism among agricultural and other poorly fed out-of-door labourers.

Sudoriparous Glands (L., *sudo*, I sweat, and *paro*, I prepare).—The sudoriparous or sweat glands are minute tubular glands diffused through the skin in enormous numbers, which excrete the perspiration from the blood. They also exhale minute quantities of carbonic acid and nitrogen gases.

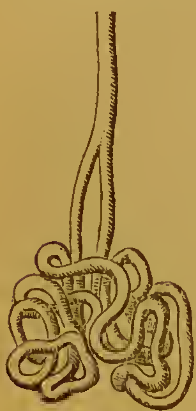


Fig. 52.—Sudoriparous Gland.

It has been estimated that there are, on an average, about 2,800 pores in each square inch of the skin; also that there are about 2,500 square inches of skin on the surface of the body. There are, therefore, upwards of 7,000,000 sudoriparous glands with their ducts. The tube of each gland is about one-quarter inch in length; if united they would extend a distance of twenty-eight miles. The perspiration tubing thus forms twenty-eight miles of sewerage for draining away the impurities of the human blood. The extent of these preparations for its purification should enable us to form some idea of the great importance of daily ablution or bathing as a means of health.

The Sebaceous or Fat-forming Glands (L., *sebum*, fat) are little sacculated glands which secrete a fatty or oily substance for lubricating the skin and preventing its drying and cracking. They are most abundantly diffused on the scalp and those parts of the body supplied with hair, and generally open into hair follicles. They do not exist in the palms of the hands and in those parts of the body which are not supplied with hairs. Some of the largest exist on the face, and particularly on the nose.

Hair and Baldness.—Hairs are peculiar modifications of the cuticle. They exist on nearly all parts

of the surface of the body, except on the palms of the hands and the soles of the feet. They vary in colour and other characteristics in various parts of the world, and form one of the distinguishing features of race.

Hairs are set obliquely in little depressions or follicles in the true skin, termed hair follicles. At the bottom of each hair follicle is a minute projecting body, the hair papilla, upon the health and vitality of which depends the growth of the hair. Each papilla is supplied with the blood necessary for its nutrition and for the growth of the hair by a minute capillary artery. When its circulation is enfeebled or arrested the growth of the hair suffers or entirely ceases, producing baldness. If the baldness has been of long duration, the mouths of the hair follicles become closed up and it becomes incurable.

Structure of the Hair.—A single hair consists of a long conical fibre. It has a root, a shaft, and a point, and contains an outer layer termed the cortex, and an inner or medullary substance. The root of the hair is the whitish, bulbous enlargement at its lower extremity, by which it is inserted into the hair follicle; it is attached to and surrounds the hair papilla. When a hair is pulled out by its root it is detached from the hair papilla and follicle, taking with it its circular lining, termed its root-sheath, and it will be reproduced so long as the papilla remains healthy and uninjured.

The cortex or outside layer of the hair consists of imbricated scales (L., *imbrex*, a tile); that is, of scales which overlie each other like the tiles or slates of a roof.

The medulla, or interior substance of the hair, consists towards its root of little soft roundish cells, some of which contain the pigment cells, to the presence of which the colour of the hair is due; higher up in the shaft these cells become elongated and developed into fibres.

The Nails are the flattened, elastic, horny, protective coverings placed on the backs of the ends of the fingers and toes. They are also composed of modified epidermic cells. Each nail has a root, a body, and a free edge. The root is inserted into a groove or fold in the cutis, the body is the exposed part of the nail, and the free edge is formed by its anterior extremity.

The nails aid sensation by offering a resisting medium to the ends of the fingers, by which they are brought into more perfect contact with the body touched.

The Skin Regulates the Animal Heat.—The normal temperature of the human body is 98° to 100° F. An increase of 12° to 13° above this point always produces death. In fever the temperature of the blood sometimes rises to 106° or even 110° F.

The skin acts vigorously at high temperature, in a dry atmosphere. A person may endure a temperature of 200° to 300° F., or even higher, in a dry atmosphere, for some time, without injury, in consequence of the vigorous perspiratory action of the skin, the cooling influence of which counteracts the effect of the high external temperature. If, on the contrary, the heated air is charged with moisture, the refrigeratory action of the skin is checked, and such a temperature would not only be quite insufferable, but would speedily prove fatal if it were attempted to remain in it.

The influence of moisture in checking the perspiratory and cooling action of the skin is shown in the comparative action of a Turkish or hot-air bath and a Russian or vapour bath. In the former dry air bath a very high temperature may be borne for a considerable period without inconvenience; in the latter moist bath a much lower temperature can be borne for a short time only. A vapour bath at 120° F. cannot be en-

dured for more than ten minutes without intense discomfort; the vapour with which the bath is charged greatly diminishing the cooling influence which the skin exerts on the body.

The power of a Turkish bath to relieve the effects of a severe incipient cold is in some cases almost miraculous, and depends on its power to restore vigorous cutaneous action; but it should be used with caution, and never taken without medical advice by persons labouring under any tendency to brain or heart disease.

ANIMAL MECHANICS.

The Osseous System.

Animals are classified by means of their skeleton into two sub-kingdoms, termed respectively the Vertebrata and the Invertebrata, accordingly as they possess or are wanting in certain bones termed vertebræ. In many of the lower animals the bony fabric is collected principally on their exterior, forming an exoskeleton; but in all the higher animals, including man, the bony framework of the body is placed in the interior.

The Skeleton (Gr., *skello*, I dry), or bony framework of the human body, is one of its most characteristic structures, and consists of 249 variously shaped bones. The moveable bones are, in general, tipped with cartilage or gristle to prevent friction, and are united into one system by means of certain tough membranous bands termed ligaments (L., *ligo*, I bind).

Bone, as we usually see it, is a dry, hard, yellowish white, tough, inflexible, and very durable substance. In the living state, as it exists in the body, it is supplied with blood, and is of a decidedly pinkish colour. It is composed of animal or organic and earthy or inorganic matter. This double composition

may easily be proved by the two following simple experiments :—

AA′. Vertebral column supporting cranium.
R. Costæ or ribs.
X. Sternum or breast-bone.
Y. Clavicle or collar-bone.
B. Humerus or bone of upper arm.
C. Elbow.
D. Radius.
E. Ulna.
F. Carpal or wrist-bones.
G. Phalanges or bones of the fingers.
S. Os innominatum } forming the
W. Os sacrum . . } pelvis.
H. Head of the femur.
J. Os femoris or thigh-bone.
L. Patella or kneepan.
M. Tibia.
N. Fibula.
O. Tarsal or ankle-bones.
P. Metatarsal bones.

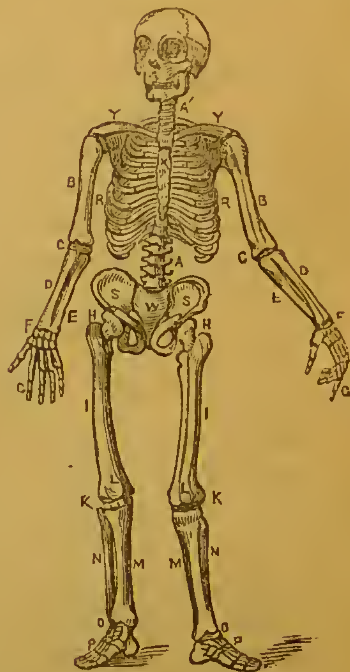


Fig. 53.—THE HUMAN SKELETON.

Functions of the skeleton {
1. To support various parts of the body.
2. To protect various parts of the body.
3. To act as passive agents of motion.

EXPERIMENT I.—Place a weighed bone in dilute muriatic acid; after some hours remove, wash, and again weigh it. It will be found to have lost about 2-3rds of its weight, and with it also to have lost its property of inflexibility, and, if a long bone, may be twisted into a knot. The acid has dissolved out its earthy matter, consisting chiefly of tribasic phosphate of lime, and rendered it flexible.

EXPERIMENT II.—Place a weighed bone in a clear bright red fire which does not smoke, for half an hour

or more. When the bone is thoroughly burnt, and all traces of blackness have disappeared, remove carefully, allow it to cool slowly, and again weigh. It will be found to have lost 1-3rd of its weight. Its animal or gelatinous constituent has been burnt away, and with it has disappeared its toughness. The hardness and inflexibility of bone is dependent upon the mode of aggregation as well as upon the constituents of the bone, since certain very flexible fish-bones contain more earthy matter than inflexible human bone.

Bones in Infancy and Old Age.—The composition of bones varies very much at different periods of life. In infancy the quantity of earthy matter in the bones is very small, being less than 1-3rd of the weight of the bone. Properly speaking, true bone does not exist in the skeleton of an infant. In middle life the earthy matter constitutes about 2-3rds of the weight of the bone, while in advanced old age the quantity present in the bone is so great as to render it exceedingly brittle.

The bones of an infant will bend and twist, but will not break. On the contrary, a very aged person can scarcely fall without breaking a bone; and when broken, in many cases the bone will not reunite.

Bones are divisible, according to their shapes, into four classes—long, short, flat, and irregular.

The Long Bones are found chiefly in the limbs, where they act as agents of support, locomotion, and prehension. A long bone consists of a shaft, or long cylindrical portion, and extremities, which are generally expanded, the upper extremity termed the head, and the lower extremity, which is generally expanded, the condyle. The shaft, or long cylindrical portion of the bone, is hollow, containing the medullary canal, which is lined by an internal periosteum, and filled with a

fatty substance termed marrow. The walls of the shaft are formed of dense compact bony tissue.

The extremities of the long bones are formed of loose, spongy, or cancellated bony tissue, covered with a very thin outer layer or crust of dense osseous tissue. The extremities are in general expanded for the attachment of the muscles and ligaments. The principal long bones are the Clavicles, Humeri, Radii, Ulnæ, Femurs, Tibiæ, Fibulæ, Metacarpal and Metatarsal bones, and the Phalanges of the toes and fingers.

The Short Bones, as those of the wrist and ankle, are composed of loose cancellated bony tissue, covered with a thin crust of compact bony substance. The cells or interspaces in the cancellated tissue are filled with marrow.

The Flat Bones are composed of two layers of compact bony tissue, enclosing more or less cancellated tissue, according to the thickness of the bone. The flat bones are the Occipital, Parietal, Frontal, Nasal, and Lachrymal bones, the Scapulæ, Innominata, Sternum, and Costæ.

The Irregular or Mixed Bones are the Vertebræ, Sacrum, Coccygis, the Temporal, Sphenoid, and Ethmoid bones; the superior and inferior Maxillaries; the Palate, inferior Turbinated, and the Hyoid bones. Their shapes vary exceedingly, and cannot be defined by any general description. They also are mainly composed of cancellated bone, with an exterior thin crust of compact bone.

The student is strongly advised to make himself familiar with the names of the various bones, and their places in the skeleton, by repeatedly pointing them out on the diagram or studying the skeleton.

Periosteum (Gr., *peri*, round, and L., *ossis*, a bone).—The bones are covered externally with a tough, fibrous,

vascular membrane, termed the periosteum, which adheres to the whole of their surface, except their ends, or those portions tipped with cartilage. A finer modification of it also lines the interior of the medullary canals.

Functions of Periosteum.—1. It makes the surface of the bone smoother, and thus lessens friction. 2. It affords a medium in which the bloodvessels break up or ramify before entering the minute orifices in the surface of the bones. 3. It serves as a medium of attachment for ligaments, tendons, and muscles.

When the periosteum of a bone is injured, that portion of the bone is very liable to necrosis, or death, in consequence of its being deprived of the blood derived through the periosteum, which is necessary for its nutrition.

Bloodvessels in Bone.—The bones are abundantly supplied with blood by means of the capillaries which ramify in the Haversian canals. The capillaries in the cancellated interior of the bones are in some cases derived from arteries which enter at the small apertures seen at the ends of the bones. But more generally they are derived from the vessels which break up in the periosteum which invests the surface of the bone.

Marrow.—The medullary canal in long bones, and the interspaces in cancellated bone, are filled with a substance termed marrow. In adult bones the marrow in the shaft is of a yellow colour, and contains 96 per cent. fat, 1 areolar tissue and vessels, and 3 per cent. of fluid and extractive matter. In very young bones it is of a reddish colour, and contains 75 per cent. of water and 25 per cent. of solid matter, consisting of albumen, fibrin, extractive matter, and a mere trace of fat.

Nerves of Bone.—Nerves have not yet been discovered in the interior of bone, but of their existence there can be but little doubt, since many injuries and affections of the bones are exceedingly painful.

The bones of the skeleton have been divided into those of the head, trunk, and extremities or limbs.

The bones of the head include those of the face and skull, or cranium.

The Skull, or Cranium, is the shell of bone which holds and protects the brain and medulla oblongata. It consists of eight bones—one frontal bone, forming the forehead; two parietal bones, forming the roof, sides, and back of the head; two temporal bones, forming the temples; one ethmoid bone; one sphenoid bone, and one occipital bone, by which it is fastened to the neck. The three last-mentioned bones form the back and base of the skull. The ethmoid and sphenoid bones cannot be seen without dissecting the skull.

The back of the skull near its base is formed by the occipital bone. This bone contains a large aperture termed the foramen magnum, through which the spinal cord passes from the brain. On each side of the foramen magnum is situated a smooth projection termed the occipital condyle. These condyles are received into two corresponding smooth cavities in the upper surface of the first cervical vertebra or neck-bone. This bone is termed the atlas. (See Fig. 56.)

By means of this joint the head is moved upwards and downwards like a see-saw, as in the act of nodding. This arrangement makes it a lever of the first order, the atlas forming its fulcrum.

Diploe (Gr., *diplous*, double).—Each of the wall-bones of the skull is composed of an inner and an outer layer of compact bony tissue, united by an interme-

diate layer of loose spongy bone termed diploë. The advantages resulting from this arrangement are—1, the greatest strength or resisting power is derived from a

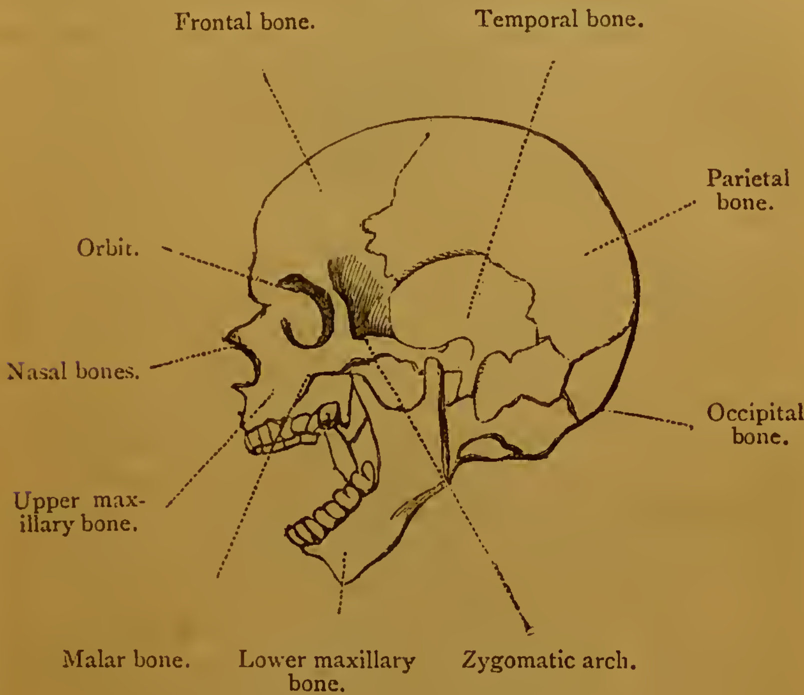


Fig. 54.—The Human Skull.

limited weight of bony substance ; 2, a crack or injury received on its external surface is not so likely to extend to the interior as it would be if the whole plate were homogeneous in its structure.

The outer table of the skull is thicker and tougher than the inner one. The inner table is denser and more brittle than the outer one, and is therefore termed the vitreous table.

Sutures (L., *suo*, I sew).—The wall-bones of the adult skull are fixed to each other by serrated or dove-

tailed edges, the teeth of one bone fitting into corresponding indentations in its adjacent bone. These joints are termed sutures.

The advantages resulting from the skull being formed of several separate bones are—1, the bones grow from their edges, and are thus enabled to adapt themselves to the growth of the brain, becoming united when the brain has attained its full growth; 2, an injury received by one bone is less likely to extend to the surrounding parts.

The wings of the sphenoid bone at the base of the skull overlap the side wall-bones of the skull, and tend to hold them together like the beams of a roof.

When the edges really dovetail together they form true sutures; but when the edges simply overlap each other, like fish-scales, they are termed squamous sutures, as in the case of the temporal bones.

The Orbits, bounded by the orbital plates, are deep, conical, hollow cavities or sockets, situated between the forehead and the cheeks. They lodge and protect the eyes, the muscles of the eyeball, the lachrymal glands, situated a little above the outer angles of the eyes, and the cushions of soft fat in which the eyes are packed to preserve them from injury.

The opening at the back of the orbits is termed the optic foramen; it gives passage to the optic nerve. At the inner angles of the eyes are two openings, one on each side, into the nose. These are termed the lachrymal grooves; they lodge the lachrymal sacs which pass the tears into the nose.

Bones of the Face.—There are fourteen bones in the face, viz.,—Two malar or cheek-bones; two upper maxillary or jaw-bones, each bone containing eight teeth; one lower maxillary or jaw-bone, containing sixteen teeth; two lachrymal bones; two spongy bones; two nasal bones, forming the bridge of the

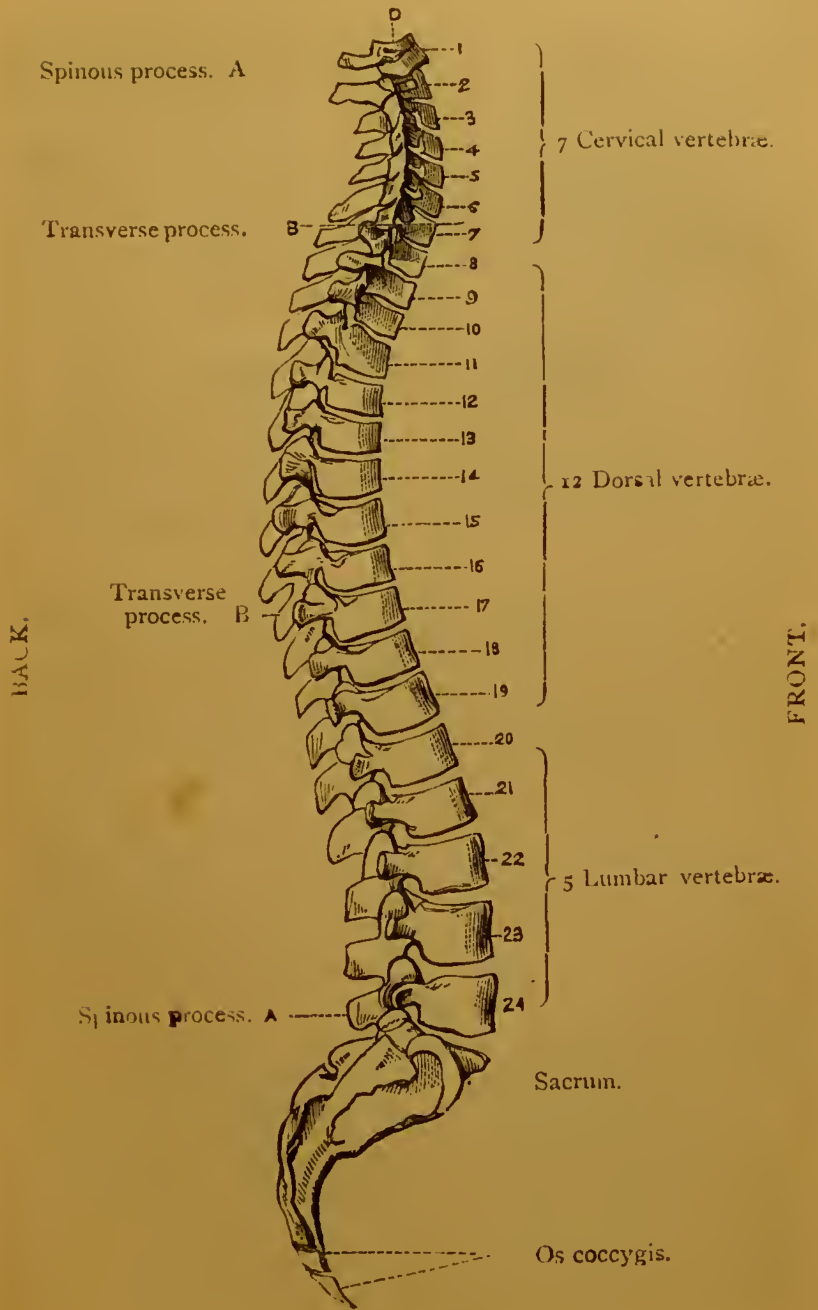


Fig. 55.—The Vertebral Column.

nose; one vomer or ploughshare bone, which divides the nose into two cavities; and the two palate-bones, forming the roof of the back of the mouth.

These bones form five cavities, in which are lodged the organs of sight, smell, and taste. The only moveable bone in the face is the lower jaw-bone.

The Bones of the Trunk comprise the back-bone, or spinal column, the ribs, the sternum, or breast-bone, and the pelvis.

The Vertebral or Spinal Column consists of twenty-four moveable vertebræ, between which are inserted pads or cushions of elastic fibro-cartilage; the sacrum, formed of five immoveable or fixed vertebræ; and the coccyx, consisting of four immoveable vertebræ.

The bodies of the twenty-four moveable vertebræ are connected together by layers or pads of fibro-cartilage, so as to form a continuous flexible column of the shape of a double S, capable of a considerable lateral or turning movement. Each vertebra contains a large hole or canal; these holes are also so arranged as to lie one on the top of the other, forming a continuous bony case termed the vertebral canal, in which the spinal cord is lodged and protected. These vertebræ are so arranged that each bone separately possesses but a very limited power of movement either in bending or turning; but the aggregate result of these individual movements is considerable. By this means the back-bone acquires great and sufficient mobility without compressing or damaging its enclosed spinal cord. Were it possible to bend the back, like the elbow, at a sudden angle, the enclosed spinal cord would be compressed, and paralysis or death would immediately follow. In consequence of the compression of the intervertebral pads of fibro-cartilage during the day

a person is not so tall at night as he is on rising in the morning.

The Atlas.—The first cervical vertebra is termed the atlas, in consequence of its supporting the head. The most distinctive character of this bone is the absence of a body, the place of the body being occupied by a groove or space in its anterior arch, into which the odontoid process of the axis is fitted. This groove is separated from the vertebral canal by the transverse ligament, which passes behind the process, strapping it into its place.

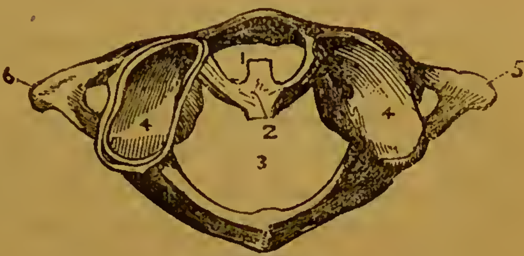


Fig. 56.—Top of Atlas, or First Cervical Vertebra.

1. Anterior groove for dentate process.
2. Ligaments for keeping dentate process in place.
3. Spinal foramen.
4. Articulating surface.
5. Foramen for vertebral artery.
6. Transverse process.

The Axis, or second cervical vertebra, forms the pivot on which the head turns, or performs its horizontal or lateral rotating movement; hence it is termed the axis vertebra. (See Fig. 57.)

Fig. 57.—Axis, or Dentate Vertebra.

1. Body. 2. Odontoid process. 3. Articulating surface. 4. Transverse process. 5. Lateral notch. 6. Foramen for vertebral artery. 7. Spinal process.

Its most distinctive character is the dentate or

odontoid process, which consists of a strong prominent tooth-like process rising perpendicularly from the upper part of the body of the bone. This process fits into a corresponding groove in the front arch of the atlas, forming the pivot on which it rotates.

It is retained in its place in the atlas by small ligaments. These small ligaments are, especially in children, easily stretched or torn, and the bones consequently displaced, the result of which is instant death. Great care should therefore always be taken in handling the heads and necks of children—as, for instance, in drying them after bathing or washing,—lest serious consequences should follow.

Structure of a Vertebra.—A vertebra usually comprises a body or centrum, which is attached to

Fig. 58.—SIDE OF A VERTEBRA.

1, 2. Lateral notches. 3. Body. 4, 4. Articulating surfaces to receive heads of ribs. 7. Transverse process. 8. Articular cavity for tubercle of rib. 9. Spinous process. 10. Tuberosity of spinous process for insertion of muscle.

those of the adjacent vertebræ by a pad of fibro-car-

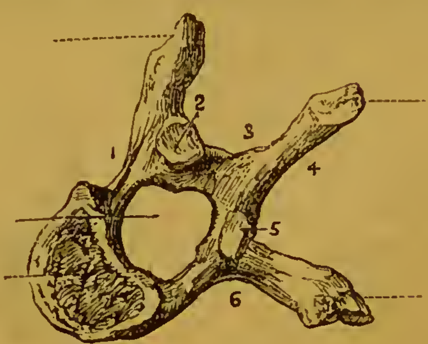


Fig. 59 —TOP OF A VERTEBRA.

tilage; transverse and spinal processes for the attachment of the muscles which raise and support the back; a central opening, forming a portion of the vertebral canal, which receives and protects the spinal cord; certain notches, which are opposed to those of the adjacent vertebræ forming the intervertebral foraminæ, which give passage to the spinal nerves; and articular processes or facets, which help to connect them with the adjoining vertebræ. These parts are plainly shown in Figs. 58 and 59.

The Thorax is the bony, or rather, osseo-cartilaginous cage intended to lodge and protect the heart and lungs; it forms the largest cavity in connection with the spine. (See Fig. 60.)

The back of the thorax is formed by the twelve dorsal vertebræ and a portion of the ribs; its sides are formed by the twelve pairs of costæ, or ribs; and its front by the ribs, the costal cartilages, and the sternum, or breast-bone.

The Costæ, or Ribs, consist of twenty-four long, thin, flat, elastic, arched bones, which are attached in pairs to the dorsal vertebræ behind, and to the sternum, by means of the costal cartilages, in front. The upper pairs are placed horizontally, but the lower ones are fixed obliquely, their anterior extremities pointing downwards. The capacity for enlargement of the chest, so essential in breathing, is due to the obliquity of the ribs. The spaces between the ribs are termed the intercostal spaces; they are filled by the intercostal muscles, which draw together and raise up the ribs. The elasticity and flexibility of the costal cartilages endow the walls of the chest with great freedom of movement. The ribs are divided into seven true ribs and five false ribs. The true ribs, which form the upper part of the thorax, are directly connected with

the sternum by means of their costal cartilages; hence they are also termed vertebro-sternal ribs. The five false ribs consist of three upper ribs, termed the vertebro-costal ribs, and two lower ones, termed the

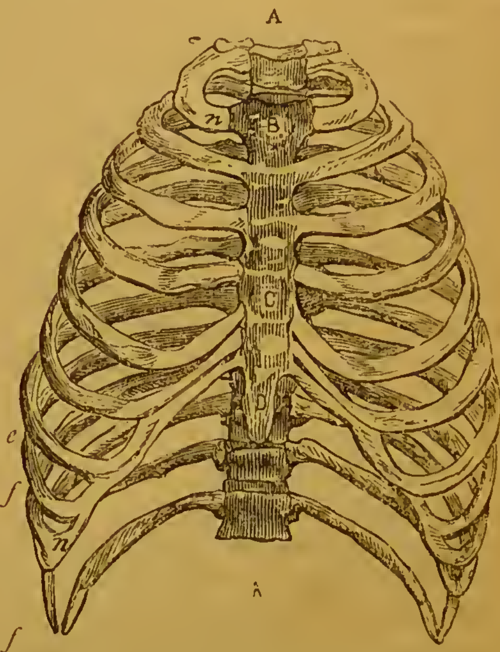


Fig. 60.—Bones of Thorax.

A, A. Dorsal vertebræ.
B, C, D. Sternum.
B. Manubrium.
C. Gladiolus.
D. Ensiform cartilage.
c, *c*. True ribs.
f, *f*. False ribs, the two lower being free or floating ribs.
n, *n*. Ten pairs of costal cartilages.

floating or vertebral ribs. The vertebro-costal ribs are attached posteriorly to the vertebræ, and anteriorly to the costal cartilages only, and therefore not directly to the sternum. The vertebral or floating ribs are attached to the vertebræ only, their anterior ends being free.

The Sternum, or breast-bone (see B C D, Fig. 60), lies in the middle of the front of the chest. It is a flat, narrow bone, consisting of three pieces.

During youth the ensiform appendage, which may be felt with the hand, is very flexible and yielding. Care should therefore be taken not to press the front

of the chest against the desk or the table while sitting, otherwise this bone will be pushed in, thus reducing the capacity of the lungs and the chest, thereby interfering with the purification of the blood and enfeebling the health. Some bootmakers have produced great depressions or cavities in their chests large enough to hold a human fist by the injurious habit of pressing the chest against the last.

The Pelvis (L., *pelvis*, a basin) is the lower girdle of bones which bounds the lowest or pelvic cavity of the trunk. (See Fig. 53.) It consists of four immoveable bones, viz. :—the two ossæ innominata (from L., *in*, not, and *nomen*, a name), or nameless bones, so called because of their shapes bearing no resemblance to any other known object ; the sacrum, and the coccyx.

The Ossæ Innominata, or the hip-bones, consist of three parts, which in early life form separate bones, but are firmly united in the adult,—the ilium, hip, or flank bone ; the ichium, or sitting bone, which supports the trunk in the act of sitting ; and the pubic bone.

The Acetabulum is the deep cup-shaped cavity or socket in the lower and outer part of the innominatum, or hip-bone, which receives the head of the thigh-bone.

The Obturator Foramen is a large aperture in the hip-bone which lessens the weight of the pelvis, and admits of the passage of nerves and bloodvessels, which derive their names from it.

The Bones of the Upper Extremities comprise the following :—The two scapulæ, or shoulder-blades, and the two clavicles, or collar-bones, which, though forming part of the trunk, are usually placed among the bones of the extremities, since it is by means of these that the upper extremities are attached

to the trunk; the two humerus bones, the two ulnar bones, the two radii, the eight carpal bones, the five metacarpal bones, and the fourteen phalanges of the fingers. To these may be added the four sesamoid bones (from Gr., *sesamon*, a kind of small grain, and *eidos*, shape), little bones which are added to the tendons of the muscles of the thumbs and the great toes, also sometimes to the tendons of other muscles, to increase their power. Their number varies in different persons, being increased by great muscular exertion.

The Scapulæ, shoulder-blades, or spade-bones, are two irregular-shaped, flattish, triangular bones, by which the arms are attached to the trunk. The scapula lies on a cushion of muscles situated on the side of the upper part of the back of the chest, and is connected with the outer extremity of the collar-bone, which keeps it in its place, by the coracoid process. (See Fig. 61.) Another process, termed the acromium process, guards the ball-and-socket shoulder joint against injury.

The Clavicle, or collar-bone (L., *clavis*, a key),

Fig. 61.—The Scapula.

1. The Spine.
2. The acromium.
3. The coracoid process.

named from its supposed resemblance to an ancient key, is a long double-curved bone, in shape very much like the letter *f*. It forms the front of the shoulder. Its inner extremity is attached to the sternum, its outer to the acromion process of the scapula. The two scapulæ act as beams, keeping the arms and shoulders out; they would otherwise fall in on to the ribs in the front of the chest. (See Fig. 31.)

The Humerus (L., shoulder), or bone of the upper arm (see Fig. 62), has a rounded head, which is

Fig. 62.

Fig. 62.—The Humerus.

1. Head.
2. Greater tuberosity.
3. Outer condyle.
4. Radial head.
5. Inner condyle.

Fig. 63.—The Radius and Ulna.

1. Shaft of ulna.
2. Its olecranon.
3. Its lower extremity.
4. Shaft of radius.
5. Head of radius.
6. Lower extremity of radius.

Fig. 63.

inserted into the glenoid cavity; a slight constriction or neck; a shaft, and a lower extremity, having two expansions or condyles, also two cavities or depres-

sions, corresponding with the heads of the bones of the fore-arm, with which it forms a hinge joint.

The Fore-arm, or lower arm, is formed of two nearly parallel long prismatic bones—the ulna and the radius. (See Fig. 63.)

The ulna (Gr., *olene*, the elbow), or cubit, which is the larger bone, is attached to the humerus by a large process at its upper extremity, termed the olecranon, which forms the elbow. Behind this process is a large, deep, articulating concavity, termed the greater sigmoid cavity, into which the humerus is inserted, forming a hinge joint.

The radius, or spoke-bone, is the outside bone of the fore-arm. It has a head, shaft, and lower extremity. (See Fig. 63.) The head, which is small, is attached to the ulna and the humerus. Its lower extremity, which is very large, is attached to the hand by two of the carpal bones, the scaphoid and semilunar.

The Hand is divisible into three segments—the carpus, or wrist; the metacarpus, or palm; and the phalanges, or fingers.

The Carpal Bones comprise eight small bones united by ligaments, and are arranged in two rows.

The Metacarpal Bones, which form the broad part or palm of the hand, consist of five long prismoidal bones, which are attached to the lower row of the carpal bones.

The Phalanges of the fingers consist of fourteen small long bones, arranged in three rows (see Fig. 53), the upper row being attached to the lower metacarpal bones. Each finger contains three phalanges; the thumbs contain two only. The upper phalange of each finger is attached to its corresponding metacarpal bone by a joint which allows it considerable freedom

Fig. 64.

Fig. 64.—THE OS FEMORIS.

1. Shaft.
2. Head.
n. Neck.
3. Greater trochanter.
4. Lesser trochanter.
5. Outer condyle.
6. Inner condyle.

Fig. 65.—THE TIBIA AND FIBULA.

1. Shaft of tibia..
2. External tuberosity of head.
3. Internal tuberosity of head.
4. Internal malleolus.
5. Shaft of fibula.
6. Head of fibula.
7. External malleolus.

Fig. 65.

of motion in every direction. All the other phalanges are connected by hinge joints, which permit of a backward and forward motion only.

The Bones of the Lower Extremities comprise two femurs, or thigh-bones; two patellæ, or knee-pans; two tibia, or shin-bones; two fibulæ, or splint-bones; seven tarsi, or ankle-bones; five metatarsi, or instep-bones: and the fourteen phalanges of the toes.

The Os Femoris, femur, or thigh-bone, is the homologue of—that is, corresponds in structure with—the humerus in the arms, and is the largest and strongest bone in the body. (See Fig. 64.) It has a head, neck, shaft, and lower extremity, with two condyles. The upper end of the shaft is furnished with two large bony protuberances, termed respectively the greater and less trochanters.

The head of the femur is large and globular, and contains a depression near its centre for the insertion of *ligamentum teres*, by which it is attached to the acetabulum in the pelvis.

The Patella, or knee-pan, is a flat triangular bone, which is situated in front of and protects the knee joint. It is inserted in the tendon of the muscles, modifying their direction and increasing their power.

The Tibia, or shin-bone, is a long, prismoidal, nearly vertical bone, situated at the front and inner side of the leg. (See Fig. 65.)

The Fibula (L., *fibula*, a buckle, the buckle of the garter being usually worn over its head), splint-bone, or small bone of the leg, is a long slender bone, parallel to the tibia, to the upper and lower extremities of which it is immoveably fixed. (See Fig. 65.)

The Foot supports the body, and is an organ of locomotion; it, like the hand, is divisible into three segments. These are the tarsus, or upper instep; the metatarsus, or lower instep; and the phalanges, or toes.

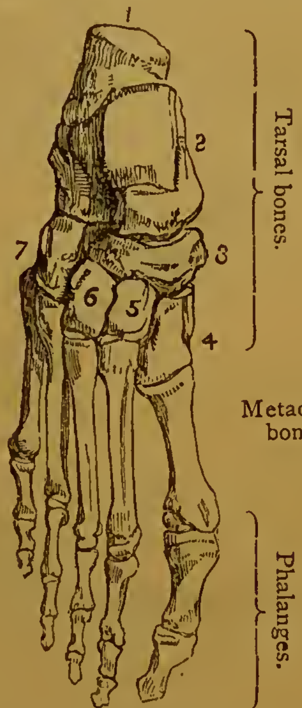
The Tarsi (Gr., *tarsos*, sole of the foot) of each foot comprise seven irregularly shaped bones—the os calcis, or heel-bone; astragalus (Gr., *astragalos*, ankle); cuboid; scaphoid, or navicular bone; and the internal, middle, and external cuneiform bones. The os calcis is the largest; it projects outward and behind, where

it receives the tendon Achilles from the muscle of the calf of the leg. It is by this muscle principally that dancers are enabled to raise themselves on the tips of

Fig. 66.—Bones of the Right Foot.

Upper Surface.

1. Os calcis.
2. Astragalus.
3. Scaphoid bone.
4. Internal cuneiform bone.
5. Middle ,, ,,
6. External ,, ,,
7. Cuboid bone.



their toes. The bones of the foot, when pulled by this muscle, act as a lever of the second order. (See Fig. 67.)

The Metatarsal Bones compose the broad part and front of the arch of each foot, or its lower instep. Each foot comprises five long bones, corresponding with the toes, and having a shaft and two extremities.

The Phalanges of the foot, or the toes, correspond with those of the hand, there being fourteen on each foot.

The Sesamoid Bones are little rounded masses

connected with the tendons; two of them are found under the metatarsal joint of each great toe.

The arch of the foot gives great elasticity and grace in walking, running, dancing, and lessens the concussion in leaping and jumping. It is said that during the Crimean war many Russian soldiers belonging to comparatively flat-footed races were disabled by the long marches from the interior.

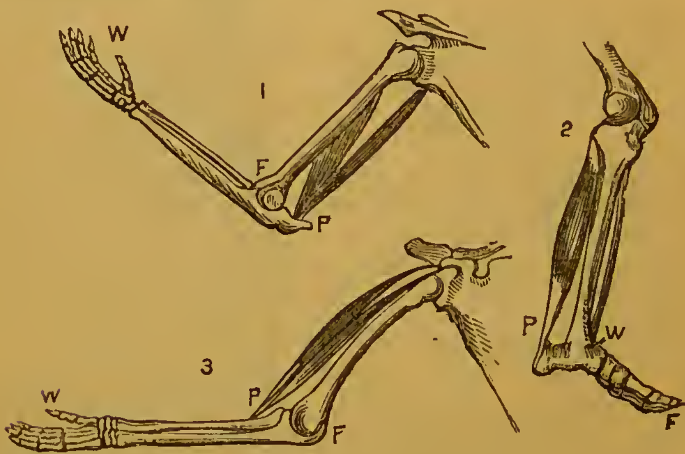


Fig. 67.—Levers in the Human Body.

1. Lever of the first order (the ulna), moved by the triceps muscle at the back of the arm.
2. Lever of the second order (the os calcis), moved by the gastrocnemius muscle of the calf of the leg.
3. Lever of the third order (the radius), moved by the biceps muscle in the front of the arm.

W represents the weight or resistance; P, the power; and F, the fulcrum, or point of support. The kind of lever depends on the relative position of these points.

In walking, the heel first touches the ground. If the bones of the leg were perpendicular over the part which first touches the ground, we should come down

with a sudden jolt; instead of which we descend in a semicircle, the centre of which is the point of the heel. When the toes reach the ground we stand on an elastic arch. A well-formed foot is high in the instep. The foot is also arched from side to side, for when a transverse section is made the bones present the appearance of a perfect arch of wedges, regularly formed like the stones of an arch in masonry.

Levers.—Certain bones of the human body are arranged as levers. Thus the ulna and the skull form levers of the first order; the os calcis forms a lever of the second order; and the radius a lever of the third order. (See Fig. 67.)

In considering the manner in which the muscles are fixed into the bones we observe everywhere the appearance of a sacrifice of mechanical power, the tendon being inserted into the bone so as to lose the advantage of a lever. The muscle which bends the fore-arm is inserted into the radius P so near the fulcrum or centre of motion in the elbow joint, and so oblique that the hand is raised at a disadvantage. But the power of the muscle is not sacrificed, since it gains more than an equivalent in the rapid motion of the hand and fingers; and since these motions are necessary in a thousand different ways, the lever power is sacrificed so as to provide for every degree and variety of motion. The elbow is bent with a certain loss of mechanical power, but when the loss is supplied by the leverage muscular power the hand descends through a greater space, and moves with a velocity which enables us to strike or to cut. The teacher will do well to give his pupils examples of the various mechanical contrivances and principles involved in the movements of the limbs.

The Articulations or Joints.

Diarthrosis, moveable joint (Gr. *dia*, through, and *arthron*, a joint), is distinguished by its mobility, or freedom of movement, as in the shoulder and hip joints.

The Muscles and Tendons, and their Functions.

The red fleshy solids of the body consist of muscle. Wherever a bone is to be moved, or an organ is to be put into motion, there is muscle. The muscles are the active agents, as the bones are in general the passive agents of motion. The muscles constitute the great mass of the body, giving it its general form and proportion.

Number and Arrangement of the Muscles.—The muscles consist of bundles or masses of muscular fibre invested in coverings of areolar tissue termed fasciæ (L., *fascis*, a bundle). These bundles are in general large and bulging at their middle or belly, but small and tapering at their extremities, which usually terminate in tendinous cords, which are attached to the ends of the adjacent bones. (See Fig. 67.) Some of the muscles are, however, circular, and many others are flat or irregularly shaped.

There are about 400 muscles in the human body, which are in general arranged in pairs. Each pair consists of two antagonist muscles, which act in opposition to each other, the one resting while the other is working; the one bending, the other straightening the limb.

Flexors and Extensors (L., *flecto*, I bend, and *ex*, out, and *tendo*, I stretch).—Those muscles which bend a limb, as the biceps muscle in front of the arm (see 3, Fig. 67), are termed flexors. Those muscles

which straighten or extend the limbs, as the triceps muscle at the back of the arm (see 1, Fig. 67), are termed extensors. A flexor and its corresponding extensor constitute a pair of antagonist muscles.

The Orbicular and Sphincter Muscles (L., *orbis*, a circle, and Gr., *sphiggo*, I contract) are circular, oval, or ring-shaped muscles, which surround and by their contraction close certain apertures or orifices, as the orbicularis oris, or circular muscle, which surrounds and closes the lips.

Abductor, Adductor, and Levator Muscles (L., *ab*, from; *ad*, to; and *duco*, I draw).—Those muscles which by their contraction draw one organ or part from another are termed abductors, as the abductor of the thumb. Those muscles which pull the organ or part inward are termed adductors, as the adductor oculi, which moves the eyeball inwards. Those muscles which raise or lift up the parts to which they are attached are termed levator muscles, as the levatores costarum. (See Fig. 31.)

Origin and Insertion.—The end of the muscle which is attached to the immoveable bone is termed its origin, and that extremity which is attached to the moveable bone its insertion; the intermediate part of the muscle, when full and thick, is termed its belly. (See Fig. 67.)

Voluntary and Involuntary Muscles (L., *volo*, I will, and *in*, not).—The muscles of prehension and locomotion act according to and under the direction of the will, and are therefore termed voluntary muscles. Those organs, the movements of which are essential to life, are supplied with muscles which act independently of the will, and are hence termed involuntary muscles. The principal involuntary muscles are the heart and the muscles of respiration and digestion.

The involuntary muscles, being independent of the will, act at all times, sleeping or waking. Were they dependent on the will, their action would immediately cease on our going to sleep, in which case circulation and respiration would both cease, and death would follow as a necessary consequence.

Muscular Contraction.—Muscles possess the property of active contractility, and tonicity, or passive contractility. When the muscles contract they become harder and about one-third shorter, but they do not lessen in real bulk. Portions only of a muscle contract at one time, those fibres which are at rest assuming a zigzag direction. When a muscle is kept long in action its various fibrils alternately rest and contract.

The Tendons are the white, glistening, tough, inelastic, flexible cords by which the ends of the muscles are attached to the bones. They consist of white fibrous tissue, and are very sparingly supplied with nerves and bloodvessels. They are well and familiarly shown in the claw of a fowl.

The muscles are well supplied with bloodvessels, nerves, and lymphatics.

ORGANS OF THE VOICE, AND THEIR FUNCTIONS.

Voice and Speech, or the utterance of words, though frequently confounded with each other, are in reality distinct phenomena. Voice is the open sound produced by the distended vocal cords when put into sufficiently rapid vibration by the passage of the air expelled through the trachea, as when we produce a continuous O, or other vowel sound. If an incision be made in the trachea below the larynx,

or voice-box, and the expired air be expelled through it, voice is not produced.

Ordinary speech consists of the voice chiselled, shaped, or sculptured into words by means of the tongue, teeth, palate, cheeks, lips, and nose. But speech is quite possible without voice, as in the case of whispering. Voice is only possible when the glottis, or breathing chink, is open; hence arises the impropriety and even danger of speaking and laughing during the processes of eating and drinking.

The acoustic principle on which the organ of the voice is constructed resembles that of a reed instrument, such as the hautboy or flageolet, which combines the principles of the vibrating tongue and the tube combined. This will be better understood after referring to the simple instrument represented by Fig. 68. On blowing through the tube, the free edges of the membranes will be put into rapid vibration, and sound waves, somewhat resembling some of the tones of the human voice, will be emitted.

Fig. 68.

The Larynx (Gr., *larugx*, the orifice of the windpipe), or organ of the voice, is a box-like structure, somewhat resembling an irregular inverted cone, situated at the top of the trachea, or windpipe, immediately in front of the œsophagus, and under the root of the tongue. It forms the well-known prominence in the upper part of the throat known as Adam's apple, or the pomum Adami; this prominence is much greater in men than in women. The larynx consists of nine cartilages, united together by ligaments; these cartilages are moved and regulated by eight intrinsic muscles. Two moveable elastic membranous folds,

termed the vocal cords, extend from the front to the back of the larynx, or voice-box. The whole is lined by delicate mucous membrane, studded with mucous

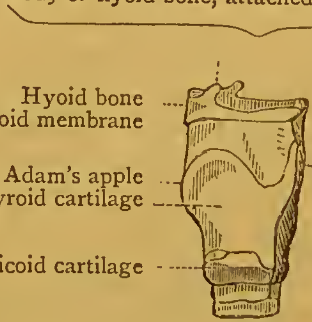


Fig. 69.—Side of the Larynx.

glands, by the secretions of which its surface is kept moist and flexible; it is also well supplied with blood-vessels, nerves, and lymphatics. In addition to the

Fig. 70.—Front View of Larynx.

membranous folds, the vocal cords previously mentioned, there are the upper and less perfectly developed folds, termed the false vocal cords.

Cartilages of the Larynx.—Besides the epiglottis, which may be considered a sort of adjunct, the larynx comprises four principal cartilages, which constitute

its framework, viz., the thyroid cartilage, the cricoid cartilages, and the two arytenoid cartilages. The remaining cartilages are the two cornicula laryngis, and the two cuneiform cartilages.

The Thyroid Cartilage (Gr., *thureos*, a shield, and *cidos*, shape) is the largest and most important cartilage in the larynx. It consists of two wings, or alæ, bent at an acute angle, which form the Adam's apple in front of the throat previously referred to. It is open behind. (See Fig. 71.) Each lateral half or wing has an upper and a lower horn, respectively termed the

Fig. 71.—Thyroid Cartilage (front).

1. Adam's apple.
2. Right wing or ala.
3. Superior cornu or horn.
4. Inferior cornu.

superior and inferior cornu, projecting from it. The upper margin of the thyroid cartilage, which is curved like the letter ∽ placed on its side, is connected by a broad membrane with the hyoid or tongue bone. Its lower front, or middle border, which does not touch the cricoid cartilage, is connected with it by the thyro-cricoid membrane; the inferior horns are attached to the outside of the cricoid cartilage, on which it performs a riding or see-saw motion, through the agency of the thyro-cricoid muscles, by which movement the tension of the vocal cords, and therefore the pitch of the voice, is determined.

The Cricoid Cartilage (Gr., *krikos*, a ring) somewhat

resembles a signet ring, being much broader behind than in front. (See Fig. 72.) It forms a complete ring, being the only entire ring in the trachea. Its

Fig. 72.—FRONT VIEW OF CRICOID AND ARYTENOID CARTILAGES.

5. Interior of back of cricoid cartilage.
6. Front of cricoid cartilage.
7. Arytenoid cartilages.

lower edge is connected by membrane with the upper ring of the trachea, on which it rests. Its upper middle border is connected with the thyroid cartilage by means of the crico-thyroid membrane (see Fig. 73); at its sides it is overlapped by the inferior horns of the thyroid cartilage, which are attached to and play upon little facets on the cricoid cartilage, producing the riding motion by which the vocal cords are adjusted as previously described.

The Arytenoid Cartilages (Gr., *arutaina*, a pitcher, and *eidos*, form) are two small pyramidal bodies, so called from the resemblance they are supposed to bear, when approximated, to the mouth of a pitcher. (See Fig. 72.) They are attached by their bases to the upper edge of the back of the cricoid cartilage, so as to admit of a backward and forward, an upward and downward, and a lateral movement; also a motion on an imaginary vertical axis passing from above, by which the corners are turned inwards or outwards, like the motion of an ordinary bell-crank. In consequence of the great mobility of these parts, and of the exquisite perfection of the muscular arrangements con-

nected with them, it is calculated that 900 changes per minute can be effected in the moveable organs of speech, and that this series of rapid changes may be sustained for hours, as in the process of reading, speaking, &c.

The Epiglottis (Gr., *epi*, upon, and *glotta*, the tongue) is a yellowish leaf-shaped, fibro-cartilaginous valve. Its apex, which is pointed downwards, is attached to the upper part of the inner angle of the thyroid cartilage; it is also attached to the hyoid bone. It lies immediately behind the root of the tongue, and during respiration and when talking inclines backwards towards the tongue. But during the process of swallowing the trachea is drawn forward under the root of the tongue; the epiglottis is bent down upon

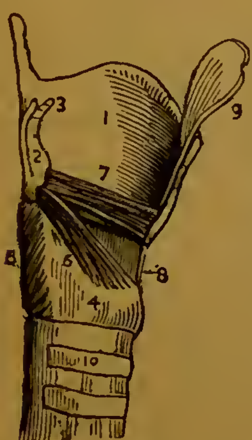


Fig. 73.—Interior of Larynx.

1. Inside of left thyroid cartilage.
2, 3. Arytenoid cartilage.
4. Cricoid ,,
5. Posterior crico-arytenoid muscle.
6. Lateral ,, ,,
7. Thyro-arytenoid muscle.
8. Crico-thyroid membrane.
9. Epiglottis.
10. Ring of trachea.

the superior opening of the larynx, which it closes after the manner of a trap-door. Its surface is lined with mucous membrane, which is studded with mucous glands.

The Upper or False Vocal Cords consist of two folds of mucous membrane at a short distance above the true vocal cords.

The Ventricle of the Larynx is the space between the true and false vocal cords.

The True Vocal Cords, or the inferior thyro-arytenoid ligaments, consist of two thin, broad, elastic, membranous folds, formed of yellow elastic fibrous tissue, and lined with mucous membrane. These folds constitute the immediate organs of the voice. One of these cords or folds is attached to the base of each of the arytenoid cartilages, and passes from it across the larynx to a recess in the thyroid cartilage on the opposite side, where it meets the end of the remaining cord, both cords being inserted at the same point. A narrow V-shaped aperture, termed the glottis, is thus formed; the vocal cords, together with the folds of mucous membrane by which they are invested, close up the whole aperture of the larynx, excepting the V-shaped chink described. All the air which passes to or from the lungs therefore passes through this chink. When the vocal ligaments are loose, and the aperture is V-shaped, we respire noiselessly; but when, by the action of the muscles, the cords are brought into a state of tension, and their edges are approximated and made parallel to each other, the act of breathing puts them into a state of rapid vibration, and sound waves, which constitute voice, are produced. The pitch of the voice depends upon the length and tension of the vocal cords.

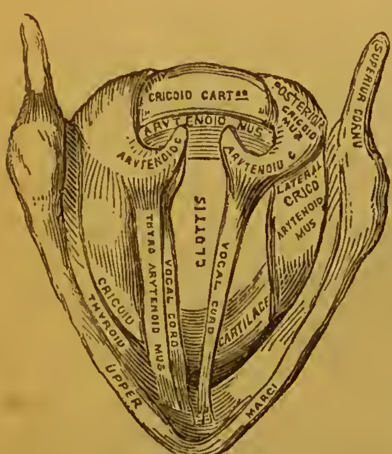


Fig. 74.—Bird's eye View of Larynx.

The Nerves of the Larynx consist of two branches of the pneumogastric nerve:—1. The superior laryngeal or sensory nerve, which is distributed to the mucous membrane; it serves, among other purposes, to test the purity of the air respired. 2. The inferior or recurrent laryngeal nerve, which supplies the power of motion to all the laryngeal muscles except the crico-thyroid muscles, which receive branches from the spinal accessory. The larynx is also supplied with nerves from the sympathetic system.

Function of Larynx.—The larynx is the organ of the voice. Its structure and action, as has been before shown, resemble those of the class of wind musical instruments known as reed instruments. An artificial larynx has been constructed by Mr. Willis, of wooden tubes and sheet india-rubber vibrating membranes, on this principle, the tones evolved from which closely resembled some of those in the human voice. More recently an improved apparatus has been constructed which is capable of producing certain sentences intelligibly. The human voice is caused by the vibration of the vocal cords; its pitch depends on the tension and consequent rapidity of the vibration of these cords. This has been proved by attaching a scale-pan to the thyroid cartilage of a dead human larynx, and blowing through the lower end of the trachea, either with the mouth or with a pair of bellows; the sound of the human voice is produced, the pitch of which is heightened by placing additional weights in the scale-pan, which by drawing down the thyroid cartilage with greater force, stretch the vocal cords more tightly. If the elastic power of the cords be injured by cold or disease, or if they be cut, hoarseness or loss of the voice (aphonia) will follow. If the inferior laryngeal nerves be cut or paralyzed, the

laryngeal muscles lose their power of contraction, and thereby of tightening and governing the vocal cords; this result being followed by loss of voice.

Singing.—In singing the vocal cords are made to vibrate isochronously—that is, in equal times. Each note requires a definite number of vibrations per second for its production.

The Loudness of the Voice depends principally on the volume of air and the rapidity and force with which it is expelled by the muscles of the chest. It also depends partly upon the resonance of the nasal and cranial cavities, and upon the shape and size of the buccal cavity and oral aperture.

The Timbre, or peculiar quality of the voice, as distinct from mere tone, depends probably upon the surfaces, shape, and the general quality of the material of the vocal organs and adjacent cavities.

Stammering, or stuttering, arises from the want of power to continue or co-ordinate the various muscular motions necessary to speech. The vocal organs are not under the complete control of the will. Thus, in pronouncing potato, the will has not the power to co-ordinate or combine the motion of the lips, the teeth, the tongue, and the glottis; the lips continuing to repeat the first, the explosive portion of the word, while the glottis remains spasmodically closed, and for some time refuses to produce the remaining portion of the word.

THE NERVOUS SYSTEM AND ITS FUNCTIONS.

The Nervous System comprises the brain, spinal cord, cerebro-spinal nerves, and a distinct system of nerves and ganglia, termed the organic, sympathetic,

or ganglionic nerves. (See Fig. 75.) It forms the highest structure in the animal organism; it does not exist, even in a rudimentary form, in the bodies of the lowest grades of animals. It is found in its highest state of development in the body of man, being most perfectly developed in the most cultivated and endowed of the human race. True education consists mainly in developing and conserving the vital force of the system, and so diverting it as to lead to the development of the highest possible type of the nervous system, care being always taken that no other part of the body is robbed of the vital force required for its own particular development and health.

The brain is the organ of the mind. Its functions are sensational, ideational, intellectual, emotional, and volitional; that is, the mental operations of Sensation, Perception, Memory, the Passions, Sentiments, Feelings, and the Will, are performed by or through the agency of the brain, and depend for their perfection and power on the quality and development of the various structures which, in the aggregate, form the brain. The various parts of the brain are differently constituted and perform different functions. But many parts of the nervous system, apparently similar in structure, perform dissimilar functions; thus no difference can be detected in the structure or chemical composition of the nerves of sensation and motion, yet their functions are entirely different. The one set of nerves (sensory or afferent) convey impressions received from without to the brain, in which they give rise to sensation; the latter set (the motor or efferent nerves) convey the effect of the will from the brain to the part, so as to produce motion in that part to which the nervous influence is conveyed.

The functions of the various parts of the nervous

system cannot be ascertained with any degree of certainty by vivisection. The functions of many organs

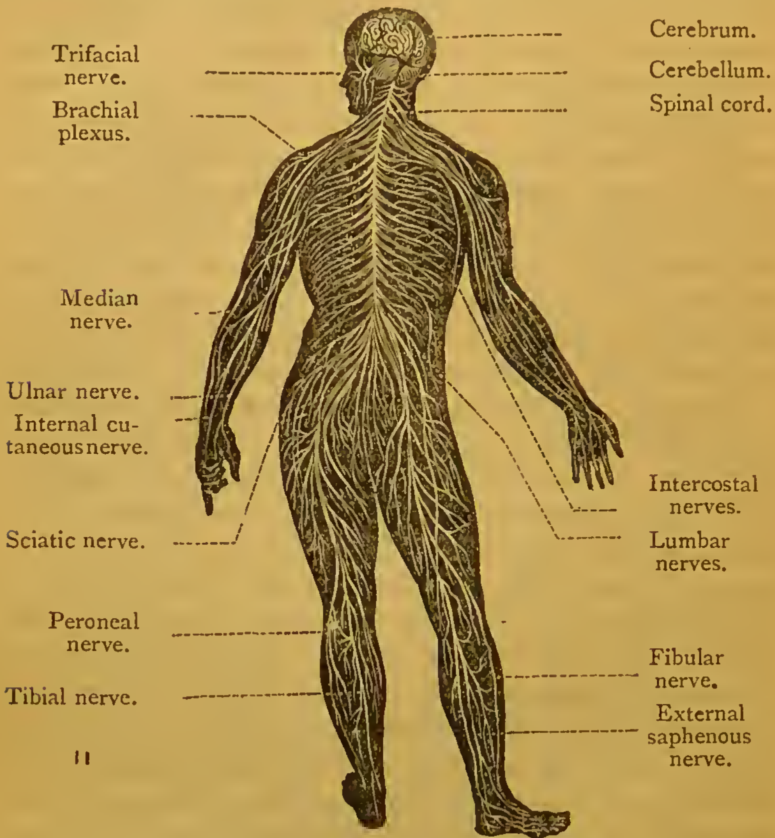


Fig. 75.—Plan of the Nervous System of Man.

of the body may, on the contrary, be readily determined by dissecting them from the living body and observing what function ceases to be performed, such function being in all probability that performed by the excised organ; but the various parts of the nervous system are so intimately related, and the sympathy between them is so perfect, that the injury of any one important part of the brain or nerves disturbs the

functions of so many others, that it becomes impossible to say which of the functions so disturbed or arrested was performed by the particular nerve or section of the brain injured. Thus a shock received at any of the nervous centres may paralyze the organs of digestion, respiration, or circulation, and produce death. A moistened leaf of tobacco placed on the skin of the upper arm will produce sickness, though none of it pass into the stomach. A cut on the finger, an offensive smell, a horrible sight, and many other influences having no immediate relation to the stomach, may, through the perfect sympathy subsisting between the various portions of the nervous system, produce effects in various parts of the body remote from those directly affected.

Parts of the Brain.—The principal parts of the brain are the cerebrum, or brain proper; the cerebellum, or lesser brain; the corpus callosum, or commissure which unites the two hemispheres of the cerebrum; the pons Varolii, or commissure which unites the two lobes of the cerebellum; and the medulla oblongata. There are also certain ganglia situated at the base of the brain, viz., the corpora striata, the optici thalami, the corpora quadrigemina, and the pineal gland. (See Fig. 76.) These ganglia are situated immediately under the corpus callosum. The olfactory lobes, two small oblong masses of grey matter which give off the true nerves of smell, are situated underneath the front lobes of the cerebrum.

From the mode in which the lower surfaces of the brain fold in upon each other, five cavities or spaces, termed the ventricles of the brain, are formed. The opposite sides of the ventricles touch each other in their interior; they are lined with the arachnoid membrane, and their surfaces are moistened by a thin

serous fluid. Among other uses they subserve, they permit of the passage of bloodvessels to and from the interior of the brain.

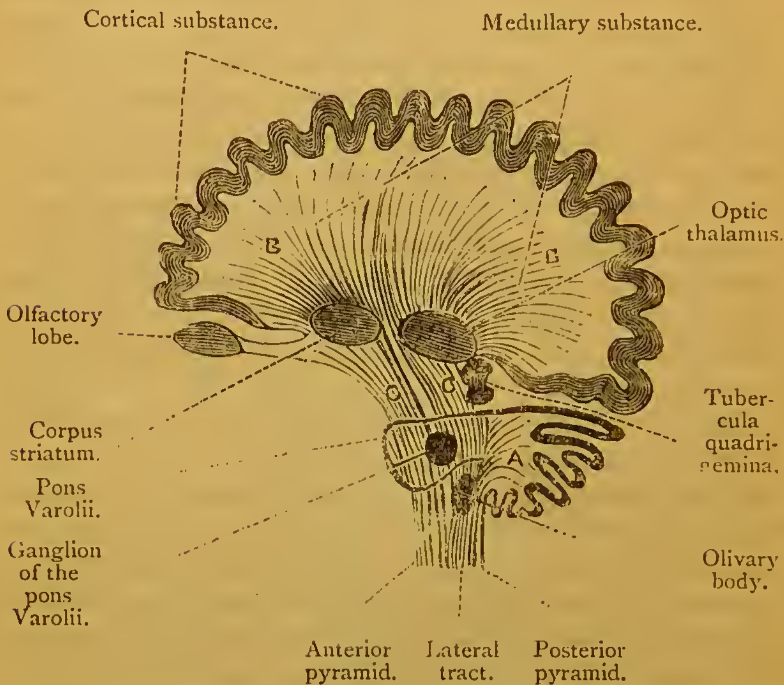


Fig. 76.—Plan of Vertical Section of the Brain and the Columns of the Medulla Oblongata.

Showing the course of the nervous fibres from the spinal cord to the various parts of the brain.

A. The cerebellum. B B. The cerebrum.
C C. The crus cerebri, or right peduncle of the cerebrum, the fibres of which pass through the corpus striatum and optic thalamus.

The brain is invested by three membranes—1, the pia mater or inner membrane, which is immediately in contact with it; 2, a middle membrane, the arachnoid membrane; and 3, an outer membrane, termed the

dura mater, which lines the interior of the skull, and forms certain canals or venous sinuses for the circulation of the blood in the cranial cavity.

The human brain weighs about 50 ounces; that of the horse about 19 ounces; the elephant, 130 to 160 ounces; and that of the whale about 80 ounces.

The Cerebrum, or Brain Proper, consists of two large, similar, and equal ovoid masses, termed hemispheres, separated by a long, deep median groove, termed the great longitudinal fissure, which passes from the front to the back of the brain. A crescent-shaped fold of the dura mater, termed the falcx, dips into the bottom of this fissure, forming a septum, which helps still further to separate the hemispheres and to retain them in their respective situations. Each hemisphere is divided into three lobes, viz., the anterior lobe, which is bounded on the under surface of the brain by the fissure of Sylvius; the posterior lobe, which covers the cerebellum; and a middle lobe, which is situated between the fissure of Sylvius and the lobe overlying the cerebellum. The surface of the cerebrum is also broken by a number of irregular fissures or sulci of various depths. The irregular folds of brain bounded by these fissures are termed convolutions. The peculiar arrangement of these sulci and convolutions, or gyri, give the brain a folded-up appearance, as shown in the diagram (see Figs. 75 and 77), their object being, in all probability, simply to increase its surface. The two hemispheres are united below the longitudinal fissure by a transverse commissure termed the corpus callosum (L., callus, hardness), which consists of a collection of white nerve fibres passing transversely from one hemisphere to the other. (See *f*, Fig. 77.) At the base of the cerebral hemispheres, below the corpus callosum, are

four narrow cavities or chambers termed the ventricles of the brain.

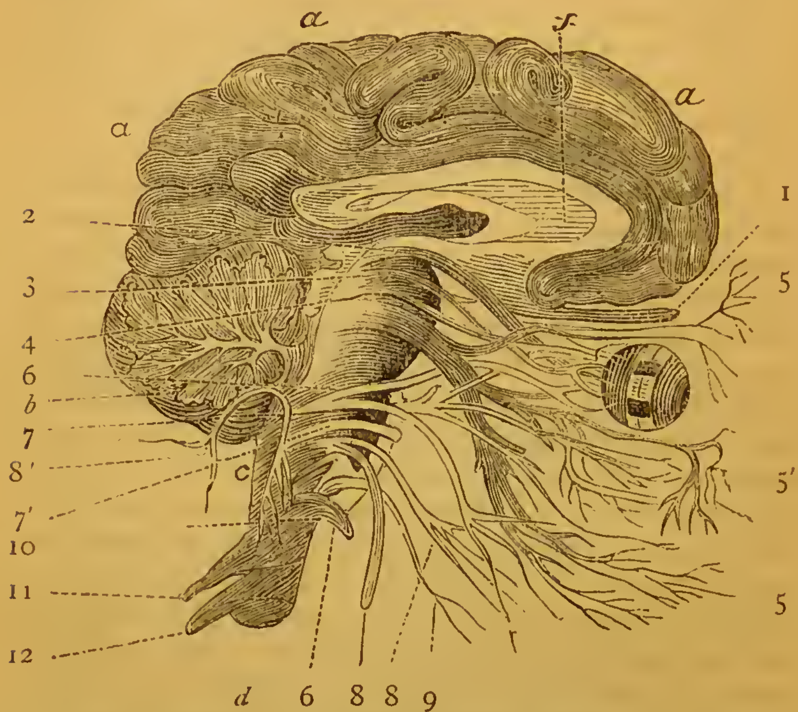


Fig. 77.—VERTICAL SECTION OF THE HUMAN BRAIN, WITH CRANIAL NERVES.

Showing the left hemispheres of cerebrum and cerebellum, separated by the great longitudinal fissure.

a a a. Cerebrum.
b. Cerebellum.
c. Medulla oblongata.
d. Spinal cord.
f. Corpus callosum.
1. Olfactory lobe.
2. Optic nerve.
3. Motor oculi.
4. Trochlear nerve.
5. Trifacial nerve.
6. Abducens nerve.
7. Portio dura of 7th nerve.
7'. Auditory nerve.
8. Glossopharyngeal nerve.
8'. Par vagum.
8''. Spinal accessory nerve.
9. Hypoglossal nerve.
10, 11, 12. Spinal nerves.

The surface (cortical layer) of the cerebral hemi-

spheres, which is of a pinkish grey colour, is composed of vesicular nerve substance.

Functions of the Cerebrum.—The cerebrum is the seat of the Intellect, Emotions, and the Will. When very small, the human being is idiotic; when removed from the lower animals, they lose their memory and power of volition. When it becomes inflamed or softened, mania or idiotcy sets in; and when it is acted upon by poisons or intoxicating agents, the intelligence and the reasoning powers are affected.

The Sensorium, or seat of sensation, is not accurately determined, but there is every reason to believe it is situated at the base of the brain, near the medulla oblongata. If the brain of a pigeon or other small animal is sliced away, it shows no signs of sensation until the knife reaches the medulla oblongata or the adjacent ganglia, when it manifests great pain.

The Cerebellum, or Lesser Brain, is situated at the base of the back of the cranium, under the posterior lobe of the cerebrum; it is contained in a distinct compartment, being separated from the cerebrum by a fold of the dura mater, termed the tentorium. The tentorium forms a roof for the cerebellum, and a floor for the support of the posterior lobe of the cerebrum.

Size and Weight of Cerebellum.—All the vertebrate animals, with one or two exceptions, have a cerebellum. The median lobe only is found in fishes and reptiles. The invertebrata do not possess a cerebellum. In man it forms about one-tenth the weight of the entire brain, and is about one-eighth the weight of the cerebrum.

The Functions of the Cerebellum are by no

means satisfactorily determined. It is supposed to regulate or co-ordinate voluntary muscular action; that is, to combine and harmonize the separate actions of the various muscles of the body, so as to produce one resultant movement.

Animals in whom the cerebellum is diseased or injured lose the power of regulating their muscular movements.

It does not seem to possess any power of sensation, injury to it apparently producing no pain. When the cerebellum of a bird or other animal is partially removed, or a cut made into its substance, it loses all power of regulating its movements, and will walk backwards or sideways, or rotate on one leg, or roll over, or perform almost any kind of abnormal movement, showing that probably, in some way or other, the cerebellum presides over or governs the voluntary muscular movements.

The Convolutions, Folds, or Gyri, are apparently devices for increasing the surface and therefore the quantity of vesicular nerve substance of the brain.

The brains of the lower animals are smooth and non-convoluted. The brains of animals of a higher grade are convoluted, but the convolutions are comparatively few and small. They are most numerous and deepest in man, their depth and extent apparently increasing with his mental power. The brains of the lowest races of mankind are said to be smoother, that is, have fewer convolutions, and these less deep, than those of the higher civilized races; so that the brains of the lower races bear a closer resemblance to the brains of the common animals than those of the higher or more civilized races.

The Pia Mater is a very delicate fibro-vascular

membrane, which immediately invests the brain and spinal cord, following their contour, dipping into the sulci or fissures, and lining the ventricles of the brain. It consists of delicate white fibrous tissue and a network of bloodvessels. Its principal functions are—1, to allow the bloodvessels which enter the skull to break

TABULAR VIEW OF THE CRANIAL NERVES AND THEIR FUNCTIONS.

Arise from the brain or pons Varolii.	1st. Olfactory nerve,	1	distributed	to the lining membrane of the nose, is the special nerve of smell.
	2nd. Optic nerve,	2	,,	to the eyeball, the special nerve of sight.
	3rd. Motor oculi,	3	,,	to the levator palpebræ of the upper eyelid, and superior, inferior, and internal straight, and the inferior oblique muscles of the eyeball—a motor nerve.
	4th. Trochlear nerve,	4	,,	to the trochlear, or pulley muscle of the eyeball and fibrils; to the lachrymal gland.
	5th. Trifacial nerve. Ophthalmic branch,	5	,,	to the orbit, eyeball, lachrymal gland, cavity of the nose, palate, gums, and teeth of upper jaw—a sensory nerve.
	Superior maxillary branch,		,,	
	Inferior maxillary branch,		,,	a motor nerve to the muscles of mastication—sensory to the tongue—the gustatory a special nerve of taste.
	6th. Abducens nerve,	6	,,	to the external straight muscle of the eye, which pulls the eye outward — a motor nerve.

Arise from the medulla oblongata.	7th.	Portia dura,	distributed	to muscles of face and of hyoid bone, and to sub-maxillary and sub-lingual glands—a motor nerve.
		Portia mollis,	,,	to the deep parts of the ear, the special nerve of hearing (auditory).
	8th.	Glossopharyngeal nerve,	,,	to tongue, pharynx, soft palate, and tonsil—a sensory nerve.
		Pneumogastric nerve, or par vagum,	,,	to muscles and mucous membrane of pharynx, larynx, trachea, bronchi, lungs, heart, and stomach—a mixed sensory and motor nerve.
		Spinal accessory nerve,	,,	to the muscles of the neck and back; forms the external respiratory nerve of motion.
	9th.	Hypoglossal nerve (or lingual)	,,	to the muscles of the tongue—a motor nerve.

up into innumerable minute branches before entering the substance of the brain; 2, to supply the cerebro-spinal fluid. It forms a close-fitting sheath to the spinal cord, and gives off a serrated membranous process, termed the denticulate ligament, also a filamentous process, termed the filum terminale, by which the spinal cord is safely retained in its proper position.

It will be seen by the above table that the cranial nerves are of three kinds—sensory, motor, and mixed.

The Arachnoid Membrane (Gr., *arachnes*, a spider, and *eidos*, appearance) is a closed serous sac which lines the brain and spinal cord.

The Cranial Nerves consist of nine pairs of nerves,—so called because they pass out of the foramina at the base of the cranium,—which are distributed symmetrically on the two sides of the

body. (See Fig. 77.) They are named according to the order in which they pass out of the skull, and the functions they perform, or the parts to which they are distributed.

The Medulla Oblongata (see Fig. 78) consists of grey and white nerve substance, the white being principally on the exterior, forming the cortical layer. The grey matter is not, however, confined exclusively to its interior, as in the case of the spinal cord, but is very generally and somewhat confusedly distributed throughout its substance. On careful examination after section its fibres are seen to decussate (cross from one side to the other) very freely.

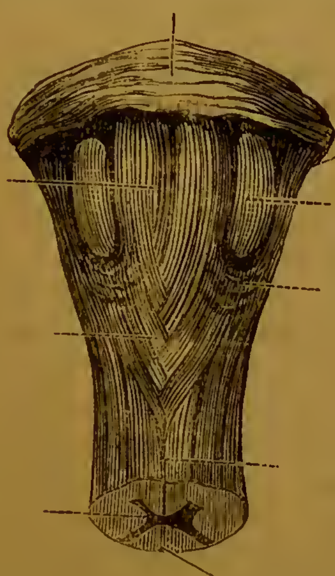


Fig. 78.—ANTERIOR SURFACE OF THE MEDULLA OBLONGATA.

The Decussation (L., decusso, I cut across), or crossing of the anterior columns (see Fig. 78), has

been suggested as the natural boundary separating the medulla oblongata from the spinal cord. Three to five bundles of fibres, termed decussating fibres, from the end of the anterior pyramids of the spinal column, cross the anterior median fissure, dividing the upper part of the fissure from the lower, and proceed to the opposite hemispheres of the brain. This explains why injury or disease on one side of the brain, as in the case of railway accidents, produces paralysis in the opposite limb or side of the body; whereas if the nerves be injured or diseased below the point of decussation, the same side of the body only may be affected.

THE SPINAL CORD AND ITS FUNCTIONS.

Appearance, Size, and Situation.—The spinal cord is the flattened cylindrical body which is contained in the vertebral canal. It is connected with the brain by the medulla oblongata, and with the various parts of the body by the thirty-one pairs of nerves it sends off laterally. It reaches from the foramen magnum of the skull to the first lumbar vertebra; is about 16 inches long, and weighs (when its nerves and membranes are detached) about 1½ ounces. It has a cervical and lumbar enlargement, from which it gives off the nerves which pass respectively to the upper and lower extremities. At its termination it gives off the leash of nerves termed (from its appearance) the cauda equina, or horse's tail. The central filament of the cauda equina, designated the filum terminale, consists of fibrous tissue; it passes down the centre of the spinal canal, and helps to retain it in its place; but it is retained in its position chiefly by a serrated ligament, which is given off on

each side of the cord from the pia mater, and which extends from the skull to the filum terminale. Each side of this ligament has a smooth interior border attached to the pia mater of the cord, and an outer serrated border, which is attached by about twenty tooth-like processes to the sides of the dura mater; this membrane has therefore been termed the denticulate ligament, or ligamentum denticulatum. It separates the roots of the posterior and anterior spinal nerves. (See Fig. 79.)

The spinal cord is divided into two lateral halves by two fissures—the anterior median fissure and the posterior median fissure, the latter being narrower but deeper than the former. Each lateral half of the cord is again divided by the line of anterior and posterior spinal nerves into three columns, viz., an anterior, lateral, and posterior column.

Structure of the Spinal Cord.—If a transverse section of the spinal cord be examined, it will be seen to consist of white and grey nerve matter (see Fig. 79); the relative position of these substances being reversed in the cord as compared with the brain, the white or tubular nerve fibre, which forms the greater part of the cord, occupying the exterior, and the grey or vesicular nerve substance the interior. The grey matter is collected in the form of two half-moon shaped masses, the concavities of which are turned outwards, their convexities being turned towards and connected with each other by a transverse commissure of grey matter. (See Figs. 78 and 79.)

Each of these masses has an anterior and a posterior cornu or horn. The anterior cornua, which are round and thick, and do not reach the surface, give off the roots of the anterior or motor nerves; and the posterior cornua, which reach the surface by irregular

or stellate processes, give off the posterior or sensory roots. The portions of the cord bounded by these nerves constitute the lateral columns. The anterior and posterior roots which emerge from the cord join as they pass through the intervertebral foraminæ. (See "Vertebral Column.") The centre of the grey commissure of the spinal cord is perforated by a minute canal about 1-100th of an inch in diameter, which is continuous with the 4th ventricle.

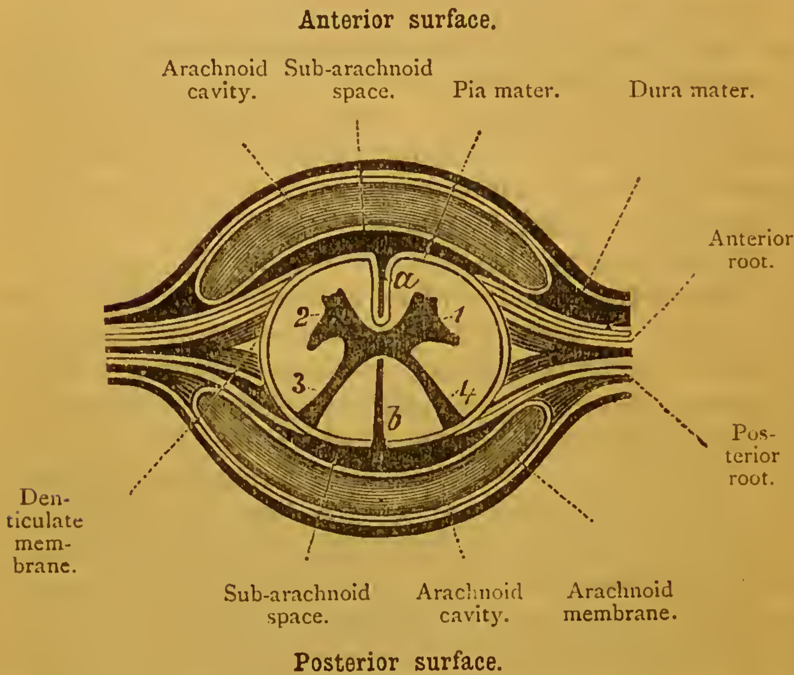


Fig. 79.—Plan of Transverse Section of Spinal Cord and its Membranes.

Showing—*a*. Anterior median fissure.
b. Posterior ,,
1, 2. Anterior cornua.
3, 4. Posterior ,,

The white fibrous portion of the spinal cord comprises transverse, oblique, and longitudinal nerve fibres, a portion only of which passes to the brain, a considerable portion of the cord consisting of commissural fibres, which unite the nerves which enter the different parts of the cord.

Functions of the Spinal Cord.—The following are probably the chief functions of the spinal cord:—1, it conducts sensory impressions to the brain; 2, it conveys motor impulses from the brain to the voluntary muscles; 3, it acts as a centre of motion altogether independently of sensation and volition, and therefore probably of the brain.

If the back is broken (dislocated), or the spinal cord is cut through by the knife or by disease, all parts below the point of injury are paralyzed, the power of sensation and voluntary motion being entirely lost.

Course of the Motor Impulses.—M. Brown Séquard has shown that the fibres of the anterior or motor nerves pass up the spinal cord and decussate or cross at the lower part of the medulla oblongata. (See 2, Fig. 80.) If, therefore, a section of one-half

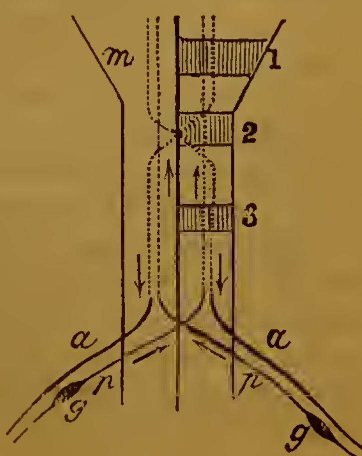


Fig. 80. — Diagram showing Course of Sensory and Motor Nerve Fibres.

a. Anterior or motor nerve fibre.
p. Posterior or sensory ,,
g. Ganglia on posterior nerves.
m. Medulla oblongata.

of the cord be made at this point, the power of movement will be lost by the muscles of both sides of the body. If the section be made a little higher, as at 1, Fig. 80, the power of movement will be lost by the muscles on the opposite side of the body only. If, on the contrary, the section be made a little lower, the muscles on the same side only will be paralyzed.

Course of the Sensory Impressions.—M. Brown Séquard has also shown that the fibres from the posterior or sensory nerves, immediately or very shortly after entering the spinal cord, cross the median line and enter the grey matter on the opposite side of the cord. It therefore follows that if one-half of the cord were severed, as in the former case, at 1, 2, or 3, Fig. 80, the power of sensation would be lost on the opposite side of the body, while that on the same side would remain perfect. It also follows that if the cord were divided longitudinally into two lateral halves, the power of sensibility would be entirely destroyed through the whole of the body.

The Spinal Nerves consist of thirty-one pairs of nerves (see Fig. 75), which emerge from the spinal cord, pass through the intervertebral foraminæ (see Figs. 55 and 59) of the back-bone, and are distributed to the various parts of the body, communicating to them the powers of sensation and motion. Each spinal nerve contains two roots—an anterior or motor nerve and a posterior or sensory nerve, which are separated as they emerge from the cord by the ligamentum denticulatum; these roots unite to form a single nerve trunk as they pass through the intervertebral foraminæ, then subdivide, giving off branches which ramify through the system. They are arranged in pairs, according to the part of the vertebral column from which they emerge:—

Cervical nerves . .	8 pairs	31 pairs.
Dorsal ,, . .	12 ,,	
Lumbar ,, . .	5 ,,	
Sacral ,, . .	5 ,,	
Coccygeal ,, . .	1 pair	

Function of the Spinal Nerves.—The spinal nerves simply act as conductors; the anterior or motor nerves act centrifugally, conveying the nervous force by which muscular contraction is produced outward; the posterior or sensory nerves act centripetally, conducting the sensory impressions inward to the brain, where they give rise to consciousness or sensation.

When a current of electricity is passed through the upper portion of a severed nerve trunk it excites a feeling of pain; when it is passed through the lower portion of the nerve it produces convulsive movements. Section of a nerve root causes the paralysis of all those parts supplied by that nerve trunk.

The Sympathetic Nervous System, also termed the organic or ganglionic nervous system, consists of a series of about thirty ganglia, united chiefly by a network of grey or gelatinous nerve fibre. It is connected with the cerebro-spinal system by white nerve fibre.

The sympathetic nerves are collected principally about the arteries and bloodvessels.

Function of the Sympathetic Nerves.—The sympathetic nerves are supposed to preside over, and, to a certain extent, to regulate, the organic functions of nutrition, digestion, and secretion, as the cerebro-spinal nerves regulate the animal system. They probably adjust and harmonize the action of respiration with that of digestion, circulation, &c., so that in a state of health the various organs perform their duty symmetrically. Their influence over the

organs of nutrition is most likely exercised through the contractile power they exercise over the walls of the minute arteries and the capillaries. It is found that if a sympathetic nerve trunk be divided, the minute arteries which it supplies with nerves become enlarged, their coats yielding to the pressure of the blood, which they are unable to withstand, in consequence of the nervous influence being withdrawn, an excess of blood forces itself into the vessels, producing congestion. If the sympathetic nerves connected with the ear of a rabbit be cut, the bloodvessels immediately swell, becoming congested, and the part grows warmer. In this way certain parts, as the eye, become ulcerated, in consequence of injury to the nerves connected with them. The sympathetic nerves also bring the various organs of the body into relation with the cerebro-spinal system, and therefore under the influence of the passions and emotions. Thus the heart of a living person might be touched and handled without the individual's being conscious of it, since it is but scantily supplied with cerebro-spinal nerves; but it is readily influenced by joy, fear, and anxiety, through the medium of the sympathetic nerves, with which it is abundantly supplied.

Reflex, Excito-motor, or **Diastaltic** actions (L., *re*, back, and *flecto*, I bend; and Gr., *dia*, apart, and *stello*, I send) are effected independently of the will, and therefore of the mind. For the performance of these actions a centre, as a ganglion or the spinal cord; an afferent, centripetal, or sensory nerve; and an efferent, centrifugal, or motor nerve, are necessary.

The afferent fibres receive the impression, which they convey to the ganglion or spinal cord; the spinal cord sends back, through the medium of the efferent nerve, a motor impulse, which excites movements in

the muscles to which the fibrils of the latter are distributed.

The winking of the eyelids, the movements of respiration, coughing, sneezing, swallowing, vomiting, peristalsis, and defecation are all instances of reflex action. The instinctive actions of the lower animals are also regarded as reflex. Certain nervous diseases, as hysteria, chorea (St. Vitus's dance), epilepsy, infantile convulsions, and tetanus, are characterized by well-marked spasmodic reflex actions. Some poisons, as strychnine, kill by the violent reflex action they excite. The mucous membrane of the alimentary canal is very sensitive to these impressions during infancy. Hence the presence of an orange pip, or of caraway seeds, may cause death by convulsions or reflex action.

THE ORGANS OF THE SENSES AND THEIR FUNCTIONS.

The Sense of Touch.—Its chief seat is the skin, the sensory nerves of which are chiefly derived from the posterior roots of the spinal nerves; their ultimate fibrils, in general, terminate in the papillæ previously described. In certain parts the sensibility is intensified by the tactile bodies, resembling the Pacinian corpuscles. (See Fig. 51.) A represents the body of the corpuscle, consisting of 30 to 60 distinct concentric laminæ or capsules; B, E, the interior cavity into which the nerve tube passes; C, its stalk, consisting of modified neurilemma; D, the nerve tube, passing up the stalk to the axis of the capsule.

The Sense of Taste resides chiefly in the tongue, but is not entirely confined to that organ; the soft

palate, the arches of the palate, and the fauces participating, though much more feebly, in that function.

The tongue is the principal organ of taste and speech; it is almost entirely composed of muscular fibre; it has a dorsum (back), tip, edge, or border, and is divided by a median line, on its upper surface, into two symmetrical halves. Its exterior is lined with mucous membrane, covered with epithelium, which becomes thick and matted, or furred, when the stomach is disordered. Its upper surface is covered with papillæ, which comprise three varieties:—1. Filiform (thread-like), which are most numerous. 2. Fungiform (mushroom-shaped). 3. Circumvallate (L., *circum*, round, and *vallo*, I dig), which consist of a central mound or club-shaped process, surrounded by a circular excavation, trench, or furrow. The number of the latter, which are situated in two oblique rows at the base of the tongue, does not usually exceed eight or ten. The three varieties just described are termed compound papillæ; they are covered by smaller papillæ termed secondary; the latter are also termed simple papillæ.

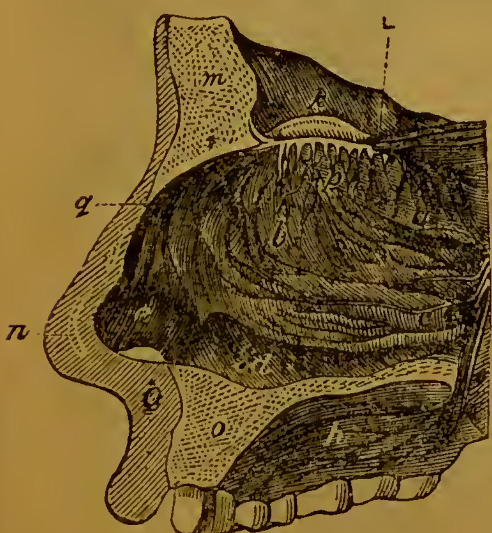
The papillæ and surface of the tongue are supplied with nervous fibrils from the lingual or gustatory branch of the fifth cranial nerve, which constitutes the special nerve of taste.

The Sense of Smell is seated in the nervous filaments of the mucous membrane which lines the upper part of the nasal cavities. By it we become conscious of the presence of odoriferous particles in the atmosphere.

The Nose is a triangular-shaped organ, comprising two symmetrical cavities, which are bounded on the exterior by bony and cartilaginous walls (the two nasal and upper maxillary bones), and separated inter-

nally in the median line by a bony and cartilaginous septum. The interior of these cavities is lined with a fibro-serous membrane, termed the pituitary or Schneiderian membrane. The olfactory nerves leave the olfactory lobes of the cerebrum, pass through a sieve-like plate of the ethmoid bone (which forms part of the roof of the nose), run between the fibrous and the mucous layers of the Schneiderian membrane, and ultimately ramify in the mucous membrane which forms the inner lining of the nasal fossæ. The fossæ or cavities of the nose open exteriorly by the two anterior nares or nostrils, and posteriorly (into the pharynx) by the two posterior nares.

The lining membrane of the nose is also freely supplied with nerves of common sensation.



a, *b*, *c*, *d*. Schneiderian membrane, lining the wall of the right nasal cavity; also showing nerves of common sensation.
e. Alæ of right nostril.
g. Upper lip.
h. Palatal nerve.
k. Olfactory lobe.
L. Cribriform plate of ethmoid bone of skull.
m. Frontal bone.
n. Nasal cartilage.
o. Upper maxillary bone (right).
p. Filaments of olfactory nerves.
q. Nasal bone.
z. Trifacial nerve.

Fig. 81.—Interior of the Nose.

A difference of opinion exists as to the immediate cause of smell, some physiologists contending with

much force that its immediate physical cause is the chemical action of the oxygen of the air on the particles of the odoriferous substance.

The Ears, or the organs of hearing, which are placed one on each side of the head, consist of arrangements

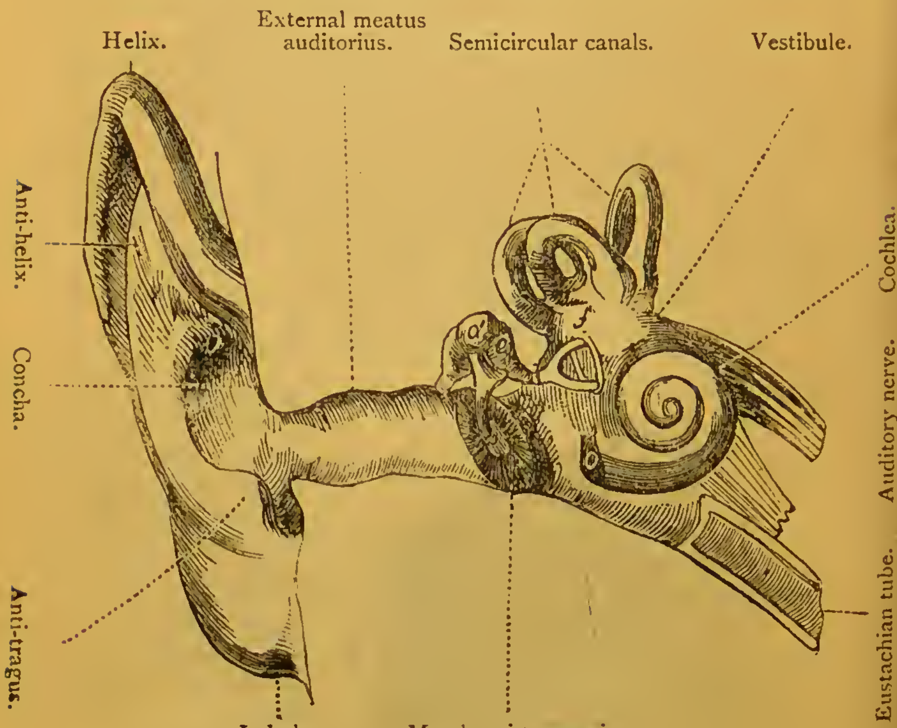


Fig. 82.—General View of the Human Ear.

d. Head of malleus, or hammer-bone.
e. Incus, or anvil-bone.
f. Fenestra ovalis.
o. Fenestra rotunda.

by which the fibrils of the auditory nerve (a branch of the 7th cranial nerves) are spread out to receive vibratory impressions transmitted from the air. Physiologists

divide the ear into three portions:—1, the external ear, comprising the pinna or auricle (the outer expanded visible portion commonly denominated the ear), an external opening or auditory canal (the meatus auditorius externus); 2, the tympanum, or middle ear, an irregular cavity traversed by a chain of ossicles (the malleus, incus, and the stapes), which connect it with the labyrinth; 3, the inner ear or labyrinth, which comprises the vestibule, cochlea (snail's shell), and semicircular canals: the outer, or bony labyrinth includes a membranous labyrinth, the interior of which is filled with a clear fluid termed the endolymph; the space between the bony and the membranous wall is filled with a clear fluid termed the perilymph. The membranous labyrinth takes the general form of, but is much smaller than, the bony labyrinth; its vestibular portion is expanded into two sacs—a smaller, the saccule, and a larger, the utricle. The saccule and the utricle contain small roundish masses of crystalline grains of carbonate of lime, termed otolithes, or otoconia (earstones, or ear powder).

The tympanum, or middle ear, communicates with the mouth by means of the Eustachian tube.

The vibratory particles, or sound waves of the atmosphere, enter the external or auditory canal, strike against and put the membrana tympani into vibration; it puts the chain of ossicles of the middle ear into vibration; they transmit their motion to the membrane of the fenestra ovalis, which communicates it to the fluid contained in the labyrinth; the fluid transmits it to the network of the auditory nerve, which is spread over the walls of the membranous labyrinth and the lamina spiralis of the cochlea; and the nerve conveys the impression to the brain (the sensorium), where it develops the sensation of sound.

The sensation of hearing sometimes originates in the brain itself without the intervention of the organs of hearing; it is then termed subjective.

The Auditory, or soft portion of the 7th cranial nerve, is distributed to the inside of the membranous labyrinth (more especially to the saccule and the utricle), and to the lamina spiralis of the cochlea.

The Sense of Sight, by means of which we are

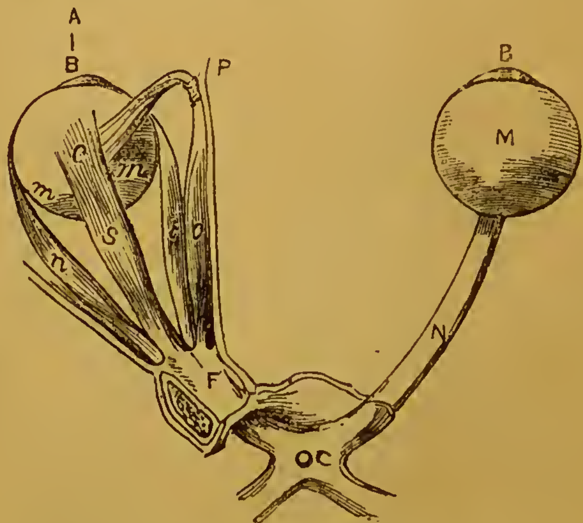


Fig. 83.—THE EYES AND THE MUSCLES OF THE LEFT EYEBALL.

A B. Line showing direction of the axis of vision.
B. Cornea.
M *m m*. Globe of the eye (sclerotic coat).
C S. Super rectus muscle (attolens).
i. Internal rectus muscle (adductor).
n. External rectus muscle (abductor).
o. Superior oblique muscle (trochlearis).
P. Pulley, or tendinous ring through which the trochlearis, or pulley muscle, works.
F. Bony wall of the optic foramen.
N. Optic nerve.
O C. Optic commissure.

brought into relation with the external world through the medium of light, is seated in the eyes.

The Eyes are organic optical instruments, by which the light is collected, brought to a focus, and thrown on to a nervous screen, on which it produces an inverted image of objects placed before it, as in the case of an ordinary magic lantern. It is supplied with certain mechanical fittings and appendages—muscular, tendinous, and glandular,—by which it is moved, cleaned, and adjusted with great accuracy. (See Fig. 83.) Sight does not take place in the eye, but in the brain.

Structure of the Eye.—The eye comprises the eyeball and contents. The eyeball is about 1 inch antero-posterior (from front to back) diameter, and 9-10ths of an inch in lateral diameter. It consists of three coats, encloses three humours and two muscles, and is supplied with nerves and arteries. (See Fig. 84.)

Coats of eyeball.	Refracting humours.	Muscles.
1. Sclerotic, cornea (outer).	Aqueous.	Ciliary.
2. Choroid, iris, ciliary processes.	Crystalline (lens).	Iris.
3. Retina.	Vitreous.	

The Sclerotic Coat (Gr., *skleros*, hard) is the thick, tough, fibrous, opaque membrane which forms the outer covering (the white) of the eye. (See Fig. 84.) It cuts like a piece of leather. The globular form of the eye depends on this coat. The sclerotic coat is absent in the front of the eye, leaving a circular opening, and is pierced behind by the optic nerve, to which it is attached like an apple to its stalk. It consists chiefly of white fibrous tissue.

The Cornea (L., *cornu*, horn) is the transparent

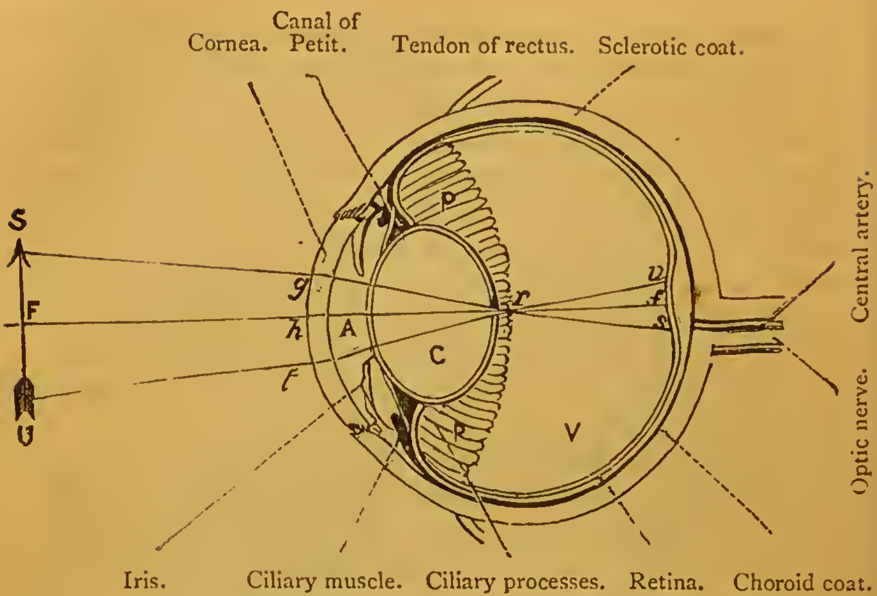


Fig. 84.—VERTICAL SECTION OF THE HUMAN EYE.

A. Aqueous humour.
C. Crystalline lens.
V. Vitreous humour.
P. Ciliary processes.
S F U. Arrow.
u f s. Inverted image of arrow.
r. Focus.
S *g*, F *h*, U *t*, rays of light before refraction.
g r s, and *t r u*, refracted rays, which pass through the pupil or opening in the Iris.

concavo-convex lens which fits into the anterior opening in the sclerotic coat. It is nearly circular, and resembles a watch-glass, fitting into and projecting from the ball of the eye as the glass does from a watch. It consists chiefly of dense laminated fibrous tissue. (See Fig. 84.) It is usually more convex in children than old persons, and in the short-sighted than the long-sighted. It forms a sort of window to the eye, sometimes becoming opaque through inflammation or disease, and producing blindness. It is supplied with nerves, and becomes very sensitive when inflamed.

The Choroid Coat (Gr., *chorion*, the outer skin of the egg, and *eidos*, shape), or middle coat (see Fig. 84), is only 1-200th of an inch thick, and consists of a delicate vascular coat, and an internal pigmentary layer, consisting of hexagonal cells, arranged like a neatly fitted mosaic pavement, and charged with dark brown or black pigment cells. The black colour of the interior of the eye, as seen through the pupil, is due to these cells; they are either absent or deficient in albinos, whose eyes, as seen through the pupil, are therefore of a pinkish colour. The apparent function of the pigment is to absorb the surplus light which would otherwise interfere with perfect vision. This coat lines the whole of the interior of the eye, excepting the back of the cornea, where it joins the ciliary ligament; it then bends in, forming about sixty folds or rays, termed the ciliary processes.

The Ciliary Ligament is a narrow whitish fibrous ring which surrounds the iris, and connects it with the sclerotic coat.

The Iris (L., *iris*, rainbow) is a thin, delicate, circular curtain, having a circular contractile perforation (the pupil) at its centre, which regulates the admission of the light to the eye.

It consists chiefly of areolar and elastic tissue, supporting capillaries, nerves, and pigment cells; it also contains a small quantity of radiating and circular muscular fibre. It is attached to the cornea by its outer margin, and is suspended in the aqueous humour. The colour and variety of appearance of the eyes of different individuals are chiefly due to this organ. The iris divides the space between the lens and the cornea into two chambers, termed respectively the anterior and posterior chambers of the eye.

The Retina (L., *rete*, a network) is the third,

inner, and most important tunic of the eye. It consists chiefly of an exquisitely delicate network of nervous fibrils, which are continuous with, and form an expansion of, the optic nerve. The optical images caused by the light which enters the eye are received on this membrane, and originate those impressions which, conveyed to the brain by the optic nerve, produce sight. The two most remarkable features of the retina are the macula lutea, or bright spot of Sömmering, and the optic pore. The former is in the line of most perfect vision; at its centre is a little depression, the fovea centralis (L., *fovea*, a pit), formerly termed the foramen centrale: the latter, the optic pore, is blind, images falling on it not being perceived by the brain; at this point the optic nerve and arteria centralis enter, and the veins leave the eye.

According to modern physiologists, the retina comprises eight distinct layers, as follows, beginning from within:—

Layers of Retina.

1. Glassy limitary membrane.
2. Fibres of optic nerve.
3. Layer of nerve cells.
4. Finely granular grey layer.
5. Inner granular layer.
6. Intermediate fibrous layer.
7. Outer granular layer.
8. Layer of bacillæ (transparent rods), forming Jacob's membrane.

It has been estimated that the mind is capable of recognising an image on the retina 1-34,500th of an inch in diameter. It has also been calculated that an impression endures on the retina about one-eighth of a second: hence, if a lighted stick be moved round quickly in a small circle, it will present the appearance of a luminous ring; hence, also, the phenomena of the thaumatrope. The apparent size of a body

depends on the angle of vision. Some persons are unable to recognise certain colours; this defect is termed colour-blindness: its exact cause is unknown.

The Aqueous Humour (L., *aqua*, water) is the clear, limpid fluid which fills the space in the front of the eye between the crystalline lens and the inner surface of the cornea. It consists of 98 per cent. of water and 2 per cent. of solid, chiefly of chloride of sodium (common salt). Its quantity does not in general exceed 4 or 5 drops. When lost by wounds it is quickly replaced; it is most probably secreted by the vessels of the iris and of the ciliary processes.

The Crystalline Lens or Humour in man is a clear, transparent, crystal-like, double convex, circular lens, about 1-3rd of an inch in diameter, and 1-5th of an inch in thickness. It lies exactly in the antero-posterior axis of the eye, separating the aqueous from the vitreous humour. It is the most important optical part of the eye. It is homogeneous to the naked eye, but when boiled or hardened by alcohol, exhibits a peculiar laminated and fibrous structure, very much resembling that of an onion. This lens sometimes becomes white and opaque, producing the disease termed cataract, and consequent blindness. Surgeons partially relieve this blindness by cutting through the coats of the eyeball, and extracting the lens, or by passing a needle through the coats of the eye into the lens, and forcing it down below the pupil, so that it shall no longer obstruct the light. The lens is enclosed in a firm, structureless, brittle, elastic, transparent membrane, termed the capsule of the lens. It is retained in its position by a membrane termed the suspensory ligament of the lens. A circular passage (the canal of Petit) exists between the margin of the lens and the suspensory ligament, which is supposed

to permit of the alteration in the shape and position of the lens required for its proper adjustment.

The Vitreous Humour or body (L., *vitrum*, glass) is the largest lens or humour in the eye. It consists of a perfectly transparent, thin, jelly-like, albuminoid fluid, enclosed in an extremely thin, delicate, transparent membrane, termed the hyaloid membrane (Gr., *hyalos*, glass), and fills 4-5ths of the globe of the eye. It is convex or spherical, except in front, where it is hollowed out into a saucer-shaped cavity to receive the back of the crystalline lens.

Nature of Light. — Light always travels in straight lines when passing through the same medium, and when passing perpendicularly from one medium into another; but when it passes obliquely from one medium into another, its course is broken, and it is bent out of a straight line, or, in other words, it undergoes refraction (L., *re*, back, and *frango*, I break). When rays of light pass through a convex lens, or magnifying glass, they are bent out of their course, brought to a focus (L., *focus*, a point), and made to cross each other, thus producing an inverted image, as illustrated by the arrow, Fig. 84.

The optical parts of the eye act upon light very similarly to the telescope and the camera obscura, and, like them, require special means of adjustment.

The Appendages of the Eye comprise the eyebrows, eyelids, conjunctiva, and the lachrymal apparatus, including the lachrymal gland and sac, and the nasal duct.

The Eyebrows consist of musculo-cutaneous arches or ridges over the eyes, which are more or less studded with hairs. They shade and protect the eye. The hairs arrest the perspiration which sometimes streams down the forehead, and would otherwise flow

into the eyes. They contain fibres from the occipito frontalis, the orbicularis palpebrarum, and the corrugator supercilii muscles.

The Palpebræ, or Eyelids, are two thin, flexible, moveable covers or lids for the protection of the front of the eyeball. Each eyelid contains a framework of fibro-cartilage, termed the tarsal cartilage, and consists (passing from without inwards) of very loose skin, areolar tissue, fibres of the orbicularis muscle, tarsal cartilage, fibrous membrane, and of an inner layer (next to the eyeball) of mucous membrane, the conjunctiva. The tarsal cartilages contain a number of sacculated tubular glands, termed the Meibomian glands. The edges of the eyelids are also fringed with a row of hairs (the eyelashes), which help to shade and protect the eye.

Lachrymal Apparatus.—The lachrymal fluid, or the tears, are secreted by small glands, lodged in depressions at the upper and outer angles of the orbits. After washing the surface of the eye they escape at the opposite angle through the puncta lachrymalia into the lachrymal canals; thence into the lachrymal sacs; and thence into the nasal ducts, which discharge them into the nose. The minute structure of the lachrymal glands resembles that of the salivary glands.

Muscles of the Eyebrows and Eyelids.—The principal muscles of the eyebrows and eyelids are the orbicularis palpebrarum, a circular or sphincter muscle, which surrounds the eye and closes the eyelids; the levator palpebræ, which raises the eyelid, and is the direct antagonist to the latter; the corrugator supercilii, which draws the eyebrow downwards and inwards, and produces the vertical wrinkles in the forehead (it also produces the expression of grief);

and the tensor tarsi, which draws the eyelid down into the globe of the eye.

The Muscles which move the Eyeball (see Fig. 83) are the four recti (straight) muscles, and the superior oblique muscle, which spring from the back of the orbit, near the optical foramen (by which the optic nerve enters the orbit); and the inferior oblique muscle, which lies directly under C S, Fig. 83, and springs from the floor of the orbit.

The superior rectus, or attolens muscle (S), moves the eye upward; the inferior rectus rolls it downwards; the internal rectus, or adductor (*i*), rolls it inwards towards the nose; the external rectus, or abductor (*n*), turns the eyeball outwards; the superior oblique (trochlearis, or pulley) muscle (*o*), which passes through a loop of tendon (P), (that acts the part of a pulley,) rotates the eye outward and downward; the inferior oblique muscle, which is the antagonist of the latter, tnrns the eye outward and upward. When the two oblique muscles act together they rotate the eye on its antero-posterior axis.

The Adjustment of the Eye to different objects and distances is effected, according to some, by the four recti muscles of the eye, which, by contracting simultaneously, alter its antero-posterior diameter and increase the convexity of the cornea. It is, however, most probably effected by the ciliary muscle (see Fig. 84), the contraction of which increases, and the relaxation diminishes, the thickness and the convexity of the crystalline lens, and brings it nearer the cornea. The iris also assists by regulating the admission of light. (See "Crystalline Lens.")

Myopia (Gr., *muo*, I close, and *ops*, the eye), or short sight, is generally caused by the too great convexity of the cornea, or crystalline lens. The rays of

light are brought to a focus too quickly; hence indistinct images of distant objects are formed on the retina. It is corrected by the use of concave spectacles.

Presbyopia (Gr., *presbus*, old), or long sight, is in general caused by the flatness or deficient convexity of the cornea or crystalline lens, which produces inability to adjust the eye to minute or near objects. It is corrected by the use of convex spectacles.

Single Vision.—No certain explanation of these phenomena is known. Probably but one object is seen, because the image produced in each eye is formed on a similar spot of the retina, and that consequently similar and equal impressions being simultaneously conveyed to the brain, but one perception is excited in the mind.

Erect Vision.—It has been suggested that an object appearing erect, while its image on the retina is inverted, is caused by the decussation, or crossing, of the fibres of the optic nerve before they enter the brain.

Binocular Vision (L., *bini*, two, and *oculus*, an eye).—Bodies are said to appear solid because seen by the two eyes simultaneously, each eye receiving a slightly different picture, which the mind combines into the notion of solidity. It is, however, doubtful whether this is really a sufficient explanation of the phenomenon, since some landscape painters, with but one eye, cultivate their art with great success.

THE TISSUES, OR STRUCTURAL ELEMENTS, AND THE MEMBRANES.

The branch of biological science which treats of the microscopic structures, or the elementary tissues, is termed Histology.

The principal tissues are White fibrous tissue; Yellow elastic tissue; Areolar, Cellular, or Connective

tissue; Adipose tissue; Cartilage, osseous tissue; Dentine; the Muscular tissues; Grey and White nervous tissue; and the Epithelial tissues.

White Fibrous Tissue consists of parallel, wavy, flexible, but inextensible, tough, and inelastic fibres (resembling a skein of silk); the diameter of its fibres has not been determined, though fibres not exceeding 1-20,000th of an inch in diameter have been observed. It contains but few nerves or bloodvessels. It forms—1, ligaments; 2, tendons; 3, membranes, as the periosteum, perichondrium, the sclerotic coat of the eye, and the dura mater, which lines the skull. It is so tough that 1,000 lbs. force are required to rupture the tendon Achilles, even after death. It has very little vitality, but is readily repaired; when boiled in water it yields gelatin.

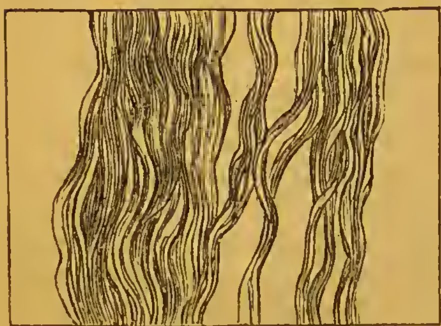


Fig. 85.—White Fibrous Tissue.

Yellow Fibrous or Elastic Tissue consists of minute, cylindrical, yellowish, extensible, flexible, and highly elastic fibres. It is nearly as elastic as india-rubber; is but slightly vascular or sensitive; is not acted upon by dilute acids; and does not yield gelatin on boiling. The yellow fibres of which it is com-

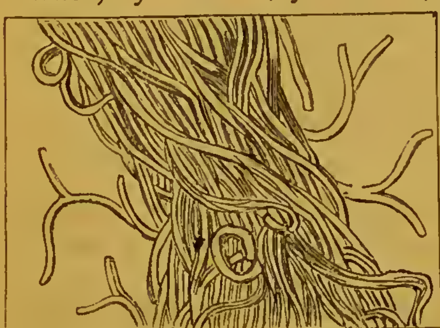


Fig. 86.—Yellow Fibrous Tissue.

posed vary from 1-10,000th inch to 1-4,000th inch in diameter; when broken, by being stretched, the ends of the fibres curl up, giving them a peculiar and characteristic appearance.

Areolar Tissue (L., *area*, an open space), or connective tissue, is the most widely diffused tissue in the body. It is a very flexible, extensible, elastic, whitish substance, possessing but feeble sensibility; it is slightly vascular, and consists of a network of bands of white and yellow fibrous tissue, containing numerous areola, or spaces, from which it derives its name. It is very abundantly diffused through the body, forming the matrix of the skin, and connecting the various tissues and organs together, and when condensed, forming sheaths or investing membranes, as the fasciæ of the muscles and the neurilemma of the nerves. It is sometimes termed cellular tissue. When treated with dilute acetic acid, numerous microscopic oval-shaped bodies, termed connective tissue corpuscles, are rendered visible.

Fig. 87.—Areolar Tissue.
Showing areolæ, or open spaces in dried tissue.

Cartilage.—Articular, or true cartilage, is an extensible, elastic, firm, flexible, tough, glistening, opal-

escent substance, varying from a bluish or pearly white

Fig. 88.—Section of Cartilage.

to a yellowish white colour. It consists of a homogeneous matrix, in which are embedded numerous nucleated cells, termed cartilage corpuscles, which vary from 1-1,300th to 1-900th of an inch in diameter. It contains neither nerves, bloodvessels, nor lymphatics, and is nourished by the liquor sanguinis, which exudes from the adjacent bloodvessels. The ends of the moveable bones are tipped with cartilage, which lessens friction by its smoothness, and diminishes concussion by its elasticity. When boiled it yields chondrin. The cartilage of which the skeleton is formed in early life is termed temporary cartilage, in consequence of its becoming ossified. The soft cartilage of the ears, eyelids, the epiglottis, larynx, intervertebral pads, and costal and nasal cartilages, possess a fibrous matrix; it is therefore termed fibro-cartilage. It is slightly vascular, and yields gelatine on boiling.

Adipose Tissue consists of clusters of nucleated vesicles or cells, 1-800th to 1-300th of an inch in diameter, consisting of transparent, homogeneous, structureless membrane, which is not more than 1-20,000th of an inch thick. The original form of the cell is spherical, but it becomes hexagonal by compression, like those of the honeycomb. Each cell is surrounded by a capillary loop, and its interior filled with a yellowish unorganized fluid. Adipose tissue neither contains nerves nor lymphatics.

Fat.—The yellowish, homogeneous, unctuous fluid which is secreted into and fills the interior of the fat cells is termed fat. It consists of two solid proximate principles, stearine and margarine, combined with a

fluid constituent termed elaine. Fat congeals or solidifies on cooling after death, forming the suet of the butcher. The formula $C_{10}H_9O$ indicates with approximate accuracy the general composition of fat.

Fat gives roundness and beauty to the human figure, helps to pack and protect the various organs, retains and supports the animal heat, and forms a store of respiratory food always available for the wants of the system when required.

Osseous Tissue, Osteine, or Bony Tissue.—If a very thin shaving of compact bone be examined under a microscope it is found to be made up of little

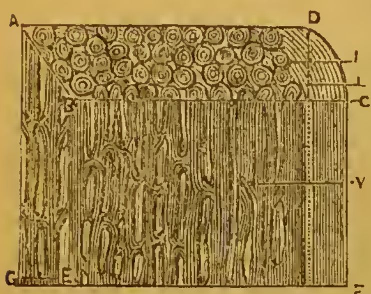
Fig. 89. — MICROSCOPIC STRUCTURE OF BONE (Transverse Section), Showing—
An Haversian canal, represented by the dark central space;
The lacunæ, forming concentric rings round the Haversian canals;
The canaliculi, which radiate from the Haversian canals through the lacunæ, giving the latter a spider-like appearance;
The bony lamellæ, marked off by the concentric rows of lacunæ.

systems, termed Haversian systems, containing—1, a central canal, termed an Haversian canal; 2, concentric solid laminæ; 3, concentric rows of lacunæ, separating the solid laminæ; 4, minute radiating tubes, termed canaliculi, which radiate or diverge from the Haversian canal, and connect it with the various cir-

cular rows of lacunæ. All true bone manifests this structure.

The Haversian canals are minute oval or circular canals discovered by the anatomist Havers. They vary from 1-2,500th to 1-200th inch in diameter, their average diameter being about 1-500th inch ; they are about 1-120th inch distant from each other. They contain the bloodvessels by which the interior of the bone is nourished.

The Lacunæ, Bone cells, or Bone corpuscles, as they have been variously termed, consist of little cells or furrows, 1-1,800th inch long, 1-3,600th inch wide, and 1-5,400th inch thick. These cells, with the canaliculi radiating through them, present a very spider-like appearance.



A, B, C, D. The surface as seen in transverse section.
B, E, F, C. The surface as seen in longitudinal section.
I. A single Haversian system, with its central canal.
G, V. Haversian systems cut longitudinally.
L. Lamellæ near the surface, destitute of Haversian systems.

Fig. 90.—Longitudinal Section of Bone.

The Canaliculi are exceedingly minute tubes, 1-20,000th to 1-1,200th inch wide. They probably aid the processes of absorption and nutrition.

Composition of Bone of Man (Berzelius).

Animal matter	31·11
Phosphate of lime	59·14
Phosphate of magnesia	1·20
Carbonate of lime	6·32
Fluoride of calcium	2·23
	100·00

The Matrix of bone consists of fibrous tissue, in which the earthy constituents of true bone are deposited.

Dentine, or tooth tissue, in many respects closely resembles bony tissue, but differs from it in containing more earthy matter, and being destitute of true

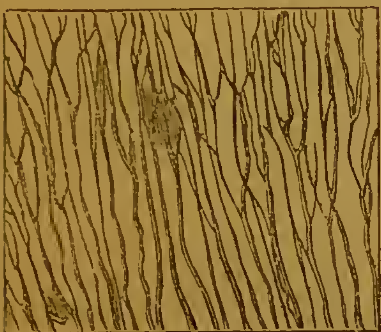


Fig. 91.—MICROSCOPIC SECTION OF DENTINE.

Showing intertubular substance, and tubuli branching dichotomously towards the surface.

Haversian canals. It contains about 72 per cent. of earthy and 18 per cent. of organic matter. When examined under the microscope it presents the appearance of a yellowish white, solid substance, having an apparently fibrous structure. This fibrous appearance is due to the presence of minute characteristic tubuli, which open and run from the pulp cavity (see page 32) to the surface of the tooth. These tubuli bifurcate, or divide into twos, towards the surface of the tooth, where they anastomose with the canaliculi (small canals) of the tooth-bone. They evidently constitute the media by which the tooth is nourished.

Muscular Tissue comprises two varieties—striated (striped) and non-striated muscular fibre. The former enters into the structure of the voluntary muscles and the heart, the latter into the structure of the organic or involuntary muscles.

Striated Muscular Fibre.—If a piece of flesh or

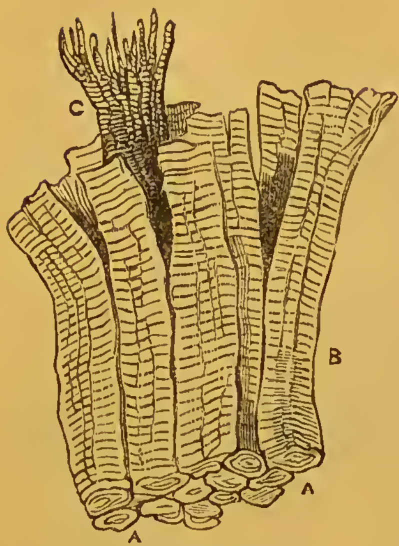


Fig. 92. — PORTION OF VOLUNTARY MUSCLE.

A A. Ends of primitive striated fibres.
B. Side of fibre, showing transverse striæ.
C. Primitive fibre split into fibrillæ.

PLAN OF STRUCTURE OF VOLUNTARY MUSCLE.

Muscle { Fasciculi { Fibres { Fibrillæ. Sarcolemma. } Areolar tissue Capillaries. Nerves. } Fascia }

muscle be examined under a magnifier, it will be seen to consist of parallel fasciuli, or bundles of fibres, bound together by sheaths of areolar tissue. If one of these fibres be examined carefully under a more powerful microscope, it will be seen to consist of still more minute parallel pale yellowish primary fibres, termed fibrillæ, which have a beaded or striated appearance, from which this class of muscular fibres derives its name and character. These fibrillæ form the ultimate or primitive structural element of striated muscular fibre ; they are about 1-400th to 1-350th of an inch in diameter. Each muscular fibre is invested

in a delicate sheath or covering of areolar tissue termed the sarcolemma. The fibres may be separated transversely into little discs, as well as longitudinally into fibrillæ.

The fibrillæ are composed of muscular fibrin or syntonin.

The **Sarcolemma,** or Myolemma (Gr., *sark*, flesh; *muon*, a muscle; and *lemma*, a husk), is a transparent, colourless, tough, elastic, but very delicate, and in general structureless membrane, which forms the tube or sheath by which each striated muscular fibre is invested. It is supposed to consist of modified areolar tissue.

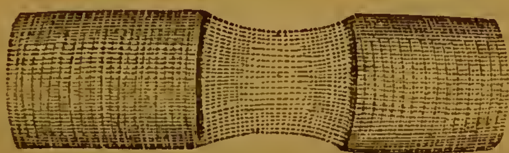


Fig. 93.—SARCOLEMMA.
A primitive muscular fibre broken across, showing the untorn sarcolemma connecting the fragments.

Organic or **Non-Striated** Muscular Fibre consists of minute nucleated fusiform (spindle-shaped) cells, united into minute flattened bands of a pale yellowish colour, 1-3,000th to 1-2,000th inch in

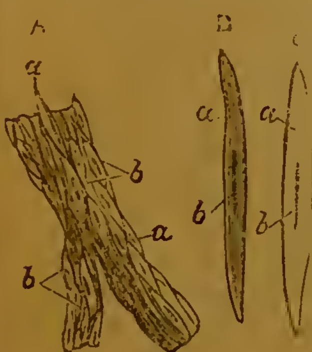


Fig. 94.—NON-STRIATED MUSCULAR FIBRE.

A. Band of fibre composed of fusiform or spindle-shaped cells, showing *a a*, the cells, and *b b*, their nuclei.
B. A single cell more highly magnified.
C. A single cell treated with acetic acid to render the elongated nucleus more distinct.

diameter. Some anatomists suppose these bands to interlace together, while other anatomists deny such to be the case, and regard them as parallel. Unstriated fibre is destitute of sarcolemma: when treated with nitric acid it splits up into its primitive structural elements, which consist of spindle-shaped cells with oblong nuclei: these cells have been termed contractile fibre cells. Unstriped muscle is found in the coats of the alimentary canal, and of the bladder, veins and arteries, gall-bladder, excretory ducts, and larger lymphatics, and in the iris, the ciliary muscle, trachea, bronchi, and the skin.

Nerve-Tissue comprises three kinds — white, tubular nerve-fibre, as in the cranial and spinal nerves; grey gelatinous nerve-fibre, as in the sym-

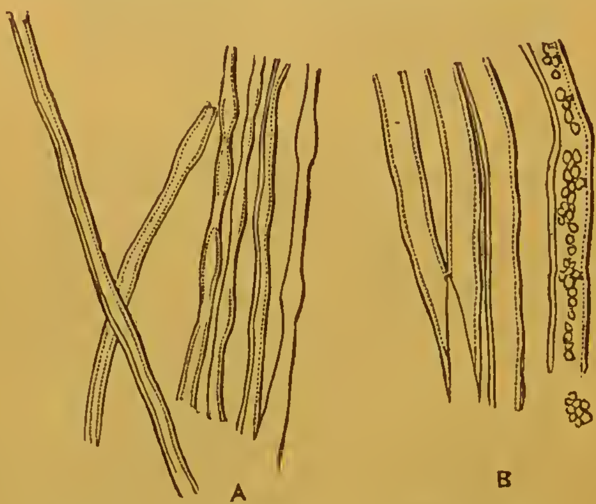


Fig. 95.—STRUCTURE OF NERVE-TUBES.

Tubular nerve-fibres:—A, from a nerve-trunk; B, from the substance of the brain.

Showing external transparent tube, central band, and intermediate white substance of Schwann. The interior of the tube to the right has become slightly grumous or granular.

pathetic system; and vesicular nerve-substance, as in the interior of the brain and the ganglia.

White Tubular Nerve-Fibre.—If a trunk of the spinal nerves be examined with a microscope, as in the case of the muscle previously mentioned, it will be seen to consist of bundles of white fibres or tubuli, on an average of from 1-4,000th to 1-2,000th inch diameter, held together by a sheath of white areolar tissue; one of these nerve-bundles is termed a funiculus (L., *funis*, a bundle). These funiculi form larger bundles termed fasciculi, which are invested in a sheath. The tube or sheath which invests the nerve-tubule is termed the neurilemma, and corresponds with the sarcolemma of primitive muscular fibre.

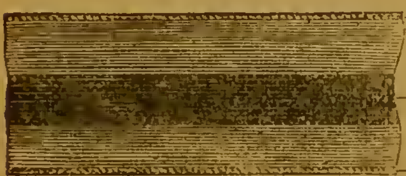


Fig. 96.—PLAN OF SECTION OF A NERVE-FIBRE.

Neurilemma (Gr., *neuron*, a nerve; and *lemma*, a husk). Some confusion exists as to the proper use of this term, some applying it to the homogeneous external sheath of the primitive nerve-tubule, others to the sheaths of the smaller funiculi, while others, again, apply it indiscriminately in both cases. It consists of a very delicate variety of areolar tissue.

A Nerve consists of a bundle of white tubular fibres enclosed in a sheath.

Gelatinous Nerve-Fibres, or Grey Nerve-fibres, belong to the sympathetic system, are exceedingly minute, flattened, soft, greyish fibres, containing numerous cell-nuclei.

Nerve Vesicles, Vesicular Neurine, or Nerve Corpuscles, consist of nucleated cells of various forms,

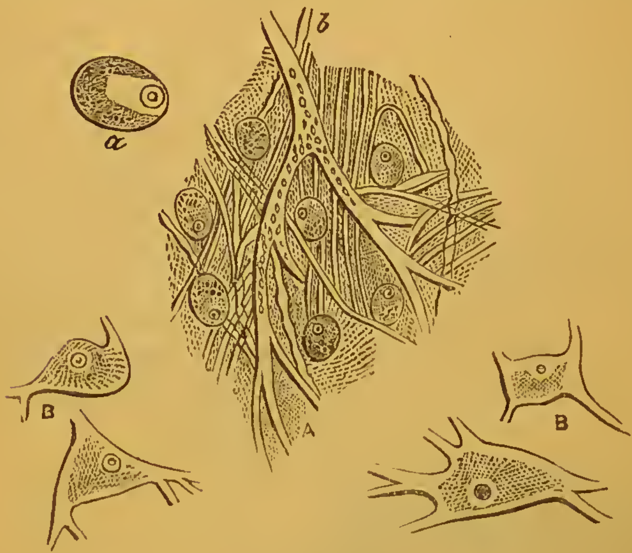


Fig. 97.—VESICULAR NERVE-SUBSTANCE.

A. Portion of a ganglion consisting of nerve-cells and fibres.
a. One of the ganglion cells more highly magnified.
b. A capillary vessel.
B. Caudate or stellate nerve-cells, or nerve-corpuscles.

designated, according to their respective shapes, as spheroidal, pyriform, or pear-shaped, caudate (tailed), and stellate (star-shaped). These bodies enter into the structure of the ganglia, and are therefore sometimes termed ganglionic cells or corpuscles. The cortical substance of the brain and the interior of the ganglia consists principally of vesicular nervous matter. The nucleolus in the nucleus forms a most characteristic feature of the nerve-cell.—(See Fig. 97.)

The nerve-cells probably generate, and the nerve-fibres simply conduct, nervous force.

Serous Membranes consist of—1, an external layer of compact areolar tissue, less abundantly supplied with bloodvessels than the corresponding lamina in mucous membrane; 2, a middle layer of basement membrane, similar to that of mucous membrane; 3, an inner single layer of tesselated epithelium on its free surface. They are always kept moist by a liquid termed the serous fluid.

The serous membranes form closed sacs, which line the interior of the great cavities of the head and trunk. The principal serous membranes are the arachnoid membrane, which lines the cavity of the skull; the pleura, which lines the lungs and cavity of the chest; the pericardium, which lines the heart; and the peritoneum, which lines the interior of the cavity of the abdomen. The serous sacs are closed sacs, one half of which is folded or tucked into the other, so as to form, as it were, an inner lining which rubs against the outer portion. The outer layer, which is attached to the walls of the cavity in which it is placed, is termed the parietal layer; the inner receives the organ to the surface of which it is everywhere attached, forming its lining membrane, and is termed the visceral layer. Their inner, free, or epithelial surfaces, which rub together, are moistened to reduce friction. When these membranes become inflamed, they tend to throw out large quantities of a liquid termed coagulable lymph, which sometimes, as in pleuritis, joins the two walls together, producing what are in surgical language termed adhesions, which seriously interfere with the freedom of motion natural to these parts. When the serous fluid is secreted in morbid quantities, it collects in the cavities, constituting dropsy, and water on the head, &c.

Serous Fluid is a thin, transparent, colourless,

albuminous fluid, resembling but thinner than the serum of the blood, which is secreted and effused on the surface of the serous membranes for reducing friction between their surfaces.

Synovial Membranes form similar but smaller closed sacs than those formed by the serous membranes, which they much resemble. The walls of the synovial sacs line the two ends of the bones of the moveable joints, and are reflected back so as also to line the fibrous capsule passing from one bone to the other. The interior of the sac is abundantly supplied with a fluid termed synovia, which lubricates the joint and lessens friction. The structure of the synovial membranes resembles that of the serous membranes.

Synovia is a transparent, yellowish, albuminous fluid, resembling but thicker than the white of an egg. It lubricates the joints and some tendons, to allow them to glide or play over each other with the least possible friction. It resembles the serum of the blood, but is thicker.

Mucous Membranes are somewhat complex structures. They consist of—1, an exterior layer of compact or consolidated areolar tissue, continuous with the ordinary subjacent areolar tissue, by which it is attached to the adjacent surfaces: this layer is well supplied with bloodvessels, though but sparingly with nerves; 2, a middle layer of structureless basement membrane; 3, an epithelial layer, on its inner or free surface, consisting of a single or multiple layer of epithelial cells. They are moistened by mucus, and possess the ordinary physical qualities of areolar tissue.—(See page 159.)

Basement Membrane is a very thin and delicate, transparent, structureless membrane, which forms

the middle layer of the skin, serous and mucous membranes. It affords a basis for the attachment of the epithelial layer, and is permeable by fluids in the processes of osmosis and endosmosis.

Epithelium Cells consist of microscopic nucleated cells, of various sizes and shapes, held together more or less firmly by a moist intercellular matrix or blastema, which line the inner or free surfaces of the serous, mucous, and synovial membranes, the free secreting surfaces of the glands (see page 158), and which compose the outer layer of the skin.

Their functions are—1, protection or defence, as in the skin and other organs, subject to contact or friction; 2, absorption, as in the columnar epithelium of the villi of the intestine, by which the chyle is absorbed; 3, secretion, as in the glands; 4, cleansing, as shown in the constant renovation and escape of the epithelial cells of the skin, the respiratory and the gastric mucous membranes.

There are four principal varieties of epithelial cells, —1, squamos or scaly, sometimes termed tesselated or pavement epithelium, as in the peritoneum, serous

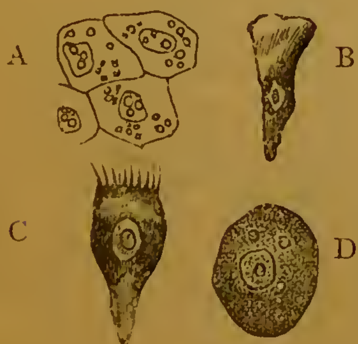


Fig. 98.—Epithelium Cells.

A. Squamos or scaly epithelium.
B. Columnar epithelium.
C. Ciliated ,,
D. Glandular ,,

membranes, and conjunctiva, or lining membrane of the interior of the eyelid; 2, columnar, as in the villi

of the intestines; 3, ciliated, or supplied with little hair-like processes, as in the trachea and air passages; 4, spheroidal, polyhedral, or glandular, as in the secreting portions of glands.

The epithelial tissues contain neither bloodvessels, nerves, nor lymphatics.

Cilia (L., *cilium*, an eyelash) are exceedingly minute hair-like, vibratory bodies, which form fringe-like processes, attached to the epithelium cells that line the surface of the smaller bronchial tubes, the nasal cavities, frontal sinuses (in the skull), lachrymal ducts, Eustachian tubes, velum palati, fauces, and larynx. They are somewhat flattened and tapering, and vary from 1-13,000th to 1-500th of an inch in length. Their function is apparently to prevent the accumulation of viscid fluids, and to propel them towards their outlet. The vibratory motion of the cilia is ceaseless during the life of the epithelium, and they continue in rapid vibration some time after the death of the animal.—(See page 152.)

Functions of Mucous Membranes.—The mucous membranes line the open cavities of the body, including the respiratory, alimentary, and urinary cavities and passages. They act—1, defensively, protecting those organs from the effects of friction and the irritation of the atmospheric air and other substances; 2, as organs of secretion, supplying a liquid by which their surfaces are kept continually moist, and by which the fluids necessary to digestion are elaborated from the blood; 3, as organs of excretion, constantly renewing and casting off epithelial cells which escape from the system.

Mucus is the transparent, structureless, colourless, slimy substance secreted and effused by the mucous membranes, as in the nose and mouth. It usually

contains cast-off epithelial scales. During inflammation of the mucous membranes it increases in quantity, becoming white, opaque, and more or less purulent, as in severe catarrh, or "cold in the head."

CELLS—CELL DEVELOPMENT AND REPRODUCTION.

The most general elementary form of organic matter is that of the cell. At one time it was supposed that all the fibres and membranes of the animal body were

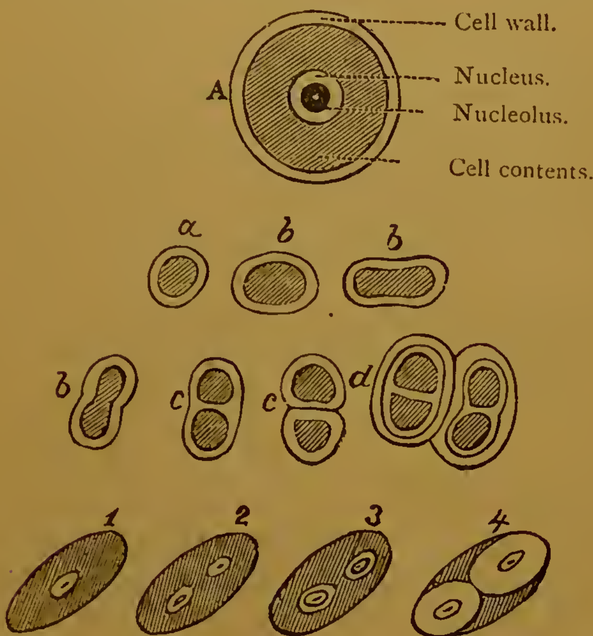


Fig. 99.—SHOWING STRUCTURE AND DEVELOPMENT OF CELLS.

A. Nucleated cell.
a, *b*, *c*, *d*. Formation of new cells by division of cell.
1, 2, 3, 4. Formation of new cells by division of nucleus.

formed out of cells, but this is now considered to be only partially true. The typical cell consists of the parts shown in the diagram, A, Fig. 99; but all these parts are not always present, or, at least, are not always distinguishable. The essential part of every perfect cell is its nucleus, which consists of germinal matter.

A Cell may originate de novo, or it may arise from a pre-existing or parent cell. All cells originate in a fluid, blastema, or formative matter. When a cell originates de novo, molecules of solid substance are formed, which coalesce to form a nucleus, or central mass, round which a delicate membrane, or cell wall, consisting of formed material, is developed. This membrane is gradually differentiated, or separated from the nucleus by the intervention of fluid or granular substance, forming the cell contents. Little granules, termed the nucleoli, are also developed in the body of the nucleus. The cell wall is, in all cases, formed of nitrogenous or albuminoid matter.

Cells are formed out of pre-existing or parent cells by two different processes of spontaneous subdivision. 1. The parent cell first elongates; then contracts somewhat in the form of an hour-glass (see *a*, *b*, Fig. 99), and ultimately divides. The process of subdivision commences in the nucleus, which separates into two parts, a double layer of cell wall being formed about them at the point of separation. 2. The nucleus itself subdivides, a new cell wall being formed about each segment of the nucleus, a number of complete cells being thus formed in the interior of the parent cell. This process of subdivision of the nucleus or germinal matter may be carried on to almost any extent in the parent cell.

The cells, having attained maturity, may undergo

the following changes:—1. They die and decay, the cell walls dissolving away; or they may burst, discharging their contents, which constitute a secretion. 2. The cells may become charged with pigment, bony or other matter. 3. The cell walls may undergo transformations: by joining together endwise, their ends being ultimately absorbed, tubes may be formed; by the closing in of these walls fibres would be formed; by their becoming flattened and joining edgewise membranes would be developed; and by their throwing out radiating or caudate processes networks or plexuses of tubuli would be formed. Some physiologists believe that organic fibres may be formed originally—that is, without the intervention of cells—by a process of fibrillation, in which the molecules of germinal matter arrange themselves primarily in the form of fibre. The most perfect elementary cells usually met with in the body are the epithelial and fat and nerve cells.

It has been ascertained, by the most careful observations, that almost every animal, from man himself downwards, originates in an egg, and it is highly probable that there is no exception to the absolute universality of this law.

As soon as the conditions necessary for development are present, the egg enters on a series of remarkable changes, which have for their ultimate object the production of a living being similar to that with which the egg originated. The first set of changes which the egg undergoes in its development are in all essential points the same in every animal. They are very curious, but space will not allow me to do more than state their result, which is the production of a peculiar organized membrane which is formed on the surface of the yolk, and is named the "blastoderm,"

or "germinal membrane;" it is in this that the embryo originates, and from the moment that the germinal membrane has been completed, development changes, as it were, its course, and thenceforth goes on in a different direction for each great division of the animal kingdom.

Let us now turn our attention to development, as observed in the highest group of animals, that known as the mammalia, which includes man himself as one of its representatives, and let us note the changes which here immediately follow the formation of the germinal membrane. A definite circumscribed oval thickening becomes apparent on the germinal membrane, and in this thickening, which is known as the "embryonic spot," a narrow longitudinal groove makes its appearance. The sides of the groove next grow upwards in the form of two ridges, which becoming higher and higher, arch over the groove, and, uniting with one another by their free edges, ultimately convert the groove into a closed tube.

In the tube thus formed the great centres of the nervous system, namely, the brain and spinal cord, originate. In the meantime the edges of the embryonic spot extend themselves downwards in a direction exactly opposed to that of the ridges just mentioned, and like them ultimately unite so as to form another tube parallel to and below that which has been formed for the nervous centres. In this second tube the blood-vascular and digestive systems are developed. The human being at the early period of his development thus consists essentially of two parallel tubes quite separate from one another, one of which gives origin to the great centres of the nervous system, and the other to the blood-vascular and digestive systems.

It is not necessary for our present purpose to pursue the progress of development further than the point to which we have thus arrived, even had we space to do so; and it is necessary to remark that the special value of the observations just described lies in the fact that the particular plan of construction on which it has been shown that the embryo is formed in the early stage of man's existence is common to him and every other member of that great division of the animal kingdom which is known as the Vertebrata, or those animals which possess a true brain and spinal cord protected by a skull and back-bone, or by some representative of these parts; while no such type of construction can be found in any other division of the animal kingdom, each being formed on its own special plan, which completely excludes that of every other.

Now we have in this a fact directly opposed to a speculation which only a few years ago had obtained very general acceptance among biologists both in this country and on the Continent, namely, that the higher animals in the course of their development passed through all the types of form which characterize the lower, and accordingly that man himself passed through every one of the great types which exist in the animal kingdom, possessing in his earliest embryonic stage the form of the lowest animal, and thence step by step passing through all the others, until he culminated in that which distinguishes the human being. To the test of a rigid observation such speculations must be subjected, and the careful study of the phenomena of development in the vertebrate embryo proves—as was shown by the great embryologist, Von Bär—that the progress is not from one type to another, but from a more general to a more special condition of one and the same type,—a

fact which demolishes at once and for ever the theory of progression from type to type, and all the speculations which have been based upon it.

All animals, then, originate in cells. Certain cells, eggs, or ova (germ cells), which are developed in the ovaries of the female, possess a higher power of differentiation than ordinary cells: this higher power is only called into operation after fusion with other cells, termed sperm cells, which are developed in the bodies of males in organs specially set apart for that function. Unless the ovum or germ cell is brought under the influence of the sperm cell it dies, decays, and liquefies; but having received that influence its higher life is brought into play, and it undergoes a series of metamorphoses, by which it is ultimately developed into an organized being, resembling in all its general characters the parent from whom it sprang. These changes may be best observed in the development of the bird from the egg during incubation; they only take place within certain temperatures, approximating to that of the body.

Changes of Animal Existence.

1st stage,	A minute particle of nitrogenous matter.
2nd ,,	Develops into an embryo having the special type and construction of the parent.
3rd ,,	Is born, works, wastes, and renovates.
4th ,,	Dies.
5th ,,	Decomposes and returns to inorganic matter.

The offspring inherits the general appearance, form, and qualities, mental and physical, of its parent. Whatever raises the type of the parent improves its offspring. On the other hand, whatever lowers the vigour, vitality, or the mental or physical qualities of the parent, deteriorates its offspring. Thus good and bad qualities alike are transmitted, and the sins of the

fathers are visited upon the third and fourth generation. These facts constitute "the hereditary transmission of qualities." In this way mental education, or the cultivation of the nervous system, determines to the succeeding generation not only a larger amount of cultivated knowledge, but also what is of much greater importance, a higher degree of intrinsic mental power. In some instances the offspring more closely resembles its grandparent, or some remote predecessor, than its immediate parent: this phenomenon is termed atavism.

DEATH.

Death, or the cessation of life or vital activity, may be described as Molecular, Local, and General or Somatic.

Molecular Death (L., *moles*, a mass, and *ule*, denoting small) consists of those series of disintegrations (or deaths) of the constituent particles of the tissues or organism which are incessantly taking place, and to which the development of the animal heat, the muscular and nervous forces, and the general phenomena of life are mainly due. These destructive changes are perpetual during life, but are compensated for or balanced by an equally perpetual series of regenerative changes, or births of new particles, by which the health and integrity of the tissues are maintained; just as a nation lives by new births, though the members composing it are continually dying off. Molecular has therefore been described as perpetual death.

Local Death.—Whatever stops the circulation of an organ or any of its parts, arrests nutrition, and causes their death or decay: this action frequently

takes place in the natural course of life, as in the shedding of the milk-teeth; but it may also occur as a consequence of disease or injury. The decay and shedding of the milk-teeth during childhood is caused by the growth of the permanent teeth, causing their crowns to press against the fangs of the milk-teeth, thereby closing the vessels by which they are nourished.

In man the epidermis or outer skin is being continually though slowly removed by a gradual process of desquamation, but some other animals, as the serpent, part with it periodically, or cast the skin.

Birds moult or cast their feathers periodically. Each feather is nourished by vessels which pass up the centre of the quill; the quill gradually thickens, contracts, and closing in upon the central bloodvessels, cuts off the supply of blood. The feather, therefore, ceases to be nourished, and is moulted or cast off as a dead product of organization. Deer cast their antlers from a similar cause, the deposition of bony matter at the base of the antler compressing and closing up the vessels, and consequently shutting off the nutritive supply.

Local death, however, sometimes results from disease or injury, as in cases of sloughing and mortification. When the circulation and consequent nutrition of a limb or organ are arrested by inflammation, pressure, the ligature of an artery, section or injury of the nerves, contusion, cold (frostbite), or from want of vigour in the circulation, it mortifies or dies and putrefies, the adjacent parts gradually sloughing or coming away in small portions, and an offensive and more or less putrid sore being formed.

If a splinter enters the skin it produces irritation and consequent inflammation of the part; the liquor

sanguinis exudes, and by its pressure on the minute bloodvessels of the adjacent parts more or less completely obstructs the circulation and arrests the nutrition of the parts, producing a small wound or ulcer. This process illustrates in a lower degree what takes place during more serious inflammation, ulceration, and mortification.

General or Somatic Death (Gr., *soma*, a body), or death of the whole body, formerly described as systemic death, is consequent on the cessation of the circulation, and is usually caused by the failure of one of three centres, which have therefore been denominated by Bichat the tripod of life,—viz., the heart, lungs, and brain.

Syncope (Gr., *sun*, together, and *kopto*, I cut).—When the immediate cause of death is the failure of the propulsive power of the heart, death is said to result from syncope.

Asphyxia.—When the immediate cause of death is obstruction to the flow of the blood by the capillaries of the lungs, death is said to be produced by asphyxia.

Coma (Gr., *koma*, lethargy).—When death is caused by failure of the action of the brain, the animal dies in a state of insensibility or unconsciousness, the heart and lungs ceasing to act from the want of the necessary nervous influence. In the latter case death results from coma.

It may be produced by certain poisons; ardent spirits; by physical shock, as a fall or a violent blow on the abdomen; or by nervous shock, as fright, passion, or excessive joy.

Death also probably sometimes begins in the blood itself, under the influence of fever and other poisons, the centres of life previously described ceasing to act

because of the want of vitality in the blood; this has been termed death by necræmia (Gr., *nekros*, dead, and *aima*, blood).

Rigor Mortis is the term applied to the stiffening of the body which ensues within a short period after general or somatic death; its exact cause is still matter of discussion among physiologists; it is generally attributed to the tonicity of the muscles, but some physiologists connect it with the coagulation of the blood. It forms a sort of demarcation between general and molecular death. After the rigor mortis the muscles soften, and putrefactive decomposition, the only sure sign of death, sets in.

Death from Old Age is consequent on the gradual exhaustion of the vitality of the system. During old age nutrition gradually falls more and more below waste; the animal heat is so reduced as to be greatly influenced by external cold; the brain and senses are greatly blunted, and the nervous power consequently greatly reduced; and the circulating current, which is exceedingly feeble, is at last brought to a stop by sheer exhaustion of vitality, and thus life is brought to a close by a quiet, painless death. This, however, but rarely happens; accident, misconduct, immorality, or disregard of sanitary laws, almost invariably determining premature death. There can be but little doubt that the human body, which is a collection of the simpler forms of organic existence, is capable like them of a certain duration of life, during which it passes through certain changes of birth, growth, maturity, and decay, and beyond which period of duration it is impossible to prolong it. But it is equally certain that the vigour of its life and the period of its duration are in general greatly limited by those premature excesses in which young people

are but too apt to indulge just at the period when their constitutions are undergoing consolidation. We cannot better conclude this solemn subject than with the following passage from Mr. Oliver Wendell Holmes's beautiful poem, "The Living Temple:"—

"O Father! grant Thy love divine
To make these mystic temples Thine!
When wasting age and wearying strife
Have sapped the leaning walls of life,
When darkness gathers over all,
And the last tottering pillars fall,
Take the poor dust Thy mercy warms,
And mould it into heavenly forms!"

RÉSUMÉ, OR MEMORY LESSONS ON IMPORTANT SUBJECTS.

WHAT BECOMES OF THE FOOD WE EAT?

Turn to Fig. 1, p. 28; Fig. 6, p. 38; Fig. 7, p. 43; and Fig. 20, p. 90.

The first process the food goes through on its way to becoming blood is called mastication. For performing this process we have provided four kinds of teeth—viz., eight incisors, four canine, eight bicuspid, or double canine, and twelve molars; these are all the instruments engaged in mastication (the tongue and saliva are merely assistants). The tongue is an organ composed entirely of muscles; it has three uses, the most important of which to mastication is keeping the food between the teeth. The next process through which the food goes is called insalivation, or otherwise the pouring of the saliva into the mouth from six glands—viz., two sub-maxillary under the jaw, two

parotid near the ear, and two sub-lingual under the tongue; it is then rolled into a ball, ready to undergo the next process, which is deglutition or swallowing. The tongue then rolls it back, and in so doing closes over a little trap-door or valve on the top of the trachea or windpipe, and prevents the food from getting to the lungs to which the windpipe leads; and the food then passes into an opening at the back of the mouth called the pharynx, at the top of which there are four tubes—two Eustachian tubes leading to the ears, and two tubes leading to the nose; these are closed over by the curtain of the soft palate, and the food then passes into the œsophagus, down which it is forced by muscular contraction. It passes then into the stomach by the cardiac orifice.

The stomach is a bag composed of three coats—an inner coat or mucous membrane, an outer skin or covering, and a middle coat or muscle, which by its contraction and expansion agitates the food while digesting. This action of the stomach is called the peristaltic action. The food while in the stomach is acted upon by the gastric juice, which, however, has only power over the flesh-forming or albuminous substances, which are gradually formed into a whitish pulpy mass called chyme, which passes through the pylorus into the intestines, where it mixes with the bile and pancreatic juice, which flow from their respective organs through the same pipe or duct into this bowel, where they separate the nutritious from the innutritious, and, in conjunction with the saliva which passes down with the food, act upon the heat-giving substances, which are fat, sugar, and starch, which the gastric juice will not act upon. And now a purer fluid is left, called chyle, which, as it passes along the intestines, is sucked up by numerous little vessels called

lacteals, or absorbents, the roots of which are called villi, which convey it up through the mesentery to the thoracic duct, a little tube which runs up by the backbone. It then empties itself into the left subclavian vein on the left side of the neck, and thus mixes with the blood.

CIRCULATION.

Turn to Fig., p. 125 ; Fig. 23, p. 127; and Fig. 24, p. 129.

The veins from all parts of the body unite to form the vena cava ascendens and the vena cava descendens, which enter the right auricle of the heart. By muscular contraction the blood is forced into the right ventricle, and is prevented returning by the tricuspid valve. The right ventricle contracts, and the blood is forced into the pulmonary arteries, and it is prevented returning by the semilunar valve. It is then carried to the lungs, where it comes in contact with the atmospheric air, the oxygen of which purifies it, and changes it from dark venous blood into bright arterial blood, which returns by the pulmonary veins to the left auricle of the heart, which contracts, and the blood is forced into the left ventricle, and is prevented returning by the mitral valve. The left ventricle contracts, and the blood is forced into the aorta or large artery, and it is prevented returning by the semilunar valve, and from thence it is carried to all parts of the body.

THE KIDNEYS.

Turn to Fig., p. 125 ; Fig. 46, p. 174 ; Fig. 47, p. 175 ; and Fig. 48, p. 176.

The kidneys are excretory organs. They are situated in the abdomen, one on each side of the backbone. When we cut one in two we find it consists

of an outer cortical portion and an inner medullary portion. When the kidneys are examined under a microscope the medullary portion is seen to consist of numerous tubes, and the cortical portion is formed of knotted ends of tubes, which end in grape-like vesicles, into each of which a minute artery enters and divides into several parts, forming a knotted tuft; these again unite and leave the vesicle, forming capillary blood-vessels upon the sides of the tubes.

From these capillaries the solid parts of the urine pass into the uriniferous tubes, while the watery part enters the little grape-like vesicles, and runs down through the tubes, washing the solid parts before it into the hollow portions of the kidneys called the calyces or cups, from which it passes into the pelvis, or basin, and from that through the ureters into the bladder.

THE LIVER.

Turn to Fig., p. 125; Fig. 39, p. 161; and Figs. 40 and 41, p. 162.

The liver is the largest gland in the body, weighing from three to four pounds. It lies in the abdomen immediately under the diaphragm, partly above and partly below the stomach on the right side. The veins from the stomach and intestines unite to form one large trunk, called the vena portæ, which plunges itself into the substance of the liver, where it divides and subdivides until it forms numerous capillary blood-vessels, which again unite and reunite to form the hepatic veins, by which the blood is carried to the vena cava ascendens. The substance of the liver consists of a mass of living cells, placed in the midst of the capillary bloodvessels. These cells are called hepatic cells, and their function is to separate the bile

from the blood. This bile is then carried to the gall-bladder by the hepatic ducts, and from the gall-bladder it is poured into the intestines to act upon the heat-giving substances of our food.

STRUCTURE AND FUNCTION OF THE LUNGS.

Turn to Fig., p. 125 ; Fig. 30, p. 141 ; Fig. 34, p. 151 ; and Fig. 35, p. 153.

The lungs are the organs of respiration. They are situated in the upper cavity of the body, called the chest, or thorax, and are placed one on each side of the head. They are surrounded by a serous membrane termed the pleura. The right lung contains three lobes, and the left two, these lobes being again subdivided into lobules. The trachea, which passes down from the pharynx in front of the œsophagus or food-pipe, divides in the upper part of the thorax into two tubes, one passing to the right and the other to the left lung, where they divide and subdivide until they ultimately end in air-sacs, the walls of which are covered with, or rather formed by air-cells, thus greatly increasing their surface. Around the outer walls of these cells are entwined capillary bloodvessels, which at one end are connected by the pulmonary arteries, by which the blood is conveyed from the heart to the lungs; and at the other end with the pulmonary veins, by which the blood is conveyed back to the heart after having been purified in the capillaries of the lungs. The lungs, then, are composed of air-tubes, air-sacs, air-cells, arteries, veins, capillaries, and areolar tissue, by which these are connected and held together.

The function of the lungs, which is to purify the blood by removing carbonic acid gas from it, and imparting to it life-giving oxygen, is performed as fol-

lows:—The ribs are raised in front, and also turned outwards, thus increasing the depth and breadth of the chest; the diaphragm, which forms a convex floor to the thorax, is depressed by the contraction of the muscles, of which it is largely composed, thus increasing the length of the chest. When the cavity of the thorax is enlarged the air rushes down the trachea, through the bronchial tubes, and swells out the air-sacs and cells in which these tubes terminate. The oxygen of this newly inspired air passes through the walls of the air-cells and capillaries into the blood by process of osmose, while by the same process carbonic acid gas passes from the blood into the air, and is expired by exactly the opposite method to that by which inspiration is performed—that is, the ribs go down and the diaphragm rises, decreasing the cavity of the thorax and expelling the air.

STRUCTURE OF VOLUNTARY MUSCLE.

Turn to Fig. 92, p. 262; and Fig. 93, p. 263.

Muscle is the lean of meat. It is composed of microscopic cells. A large number of these cells placed end to end form a fibrillus; a large number of these fibrilli bound together by sarcolemma form a muscular fibre; a large number of muscular fibres bound together by areolar tissue form a fascicle or bundle; and a number of such bundles surrounded by fascia form a muscle.

The contraction of a muscle is due to the change of form in the microscopic cells of which the fibrilli are composed. It is evident that when the cells change their form, and become shorter and thicker, the fibrilli, fibres, bundles, and muscle must do the same.

STRUCTURE AND FUNCTIONS OF NERVOUS TISSUE.

Turn to Fig. 95, p. 264; Fig. 96, p. 265; and Fig. 97, p. 266.

There are three kinds of nervous tissue :—

I. White Tubular Nerve Fibres.
II. Grey Gelatinous Nerve Fibres.
III. Grey Vesicular Nerve Fibres.

I. The white tubular fibres conduct nervous influence in connection with the cerebro-spinal system. They consist of efferent and afferent fibres; that is, fibres conveying motor influence outwards, and sensory influence or sensation inwards. When examined under the microscope each tubule is seen to consist of an inner axis cylinder, surrounded by the white substance of Schwann, and outside of this is a neurilemma or nerve-sheath.

II. The grey gelatinous fibres conduct nervous influence in connection with the sympathetic system.

III. The grey vesicular matter consists of nucleated cells, and its function is to send and receive *vis nervosa* or nervous force. It forms the outer part of the brain and the inner part of the spinal cord. It is of this tissue also that the ganglia of the sympathetic system are composed.

GLOSSARY.

Abdominal Viscera.—The stomach and intestines, liver and gall-bladder, pancreas, kidneys, &c.

Afferent (I bring).—Bringing to.

Air.—Oxygen 21 parts, nitrogen 79 parts, and a little carbonic acid gas.

Albumen.—The flesh-forming part of food (white of egg).

Albuminous Food.—Flesh-forming parts of food which are subjected to the action of the gastric juice.

Aliment.—Food, anything that nourishes the body.
Anastomosis.—To unite by open mouths, as bloodvessels.
Aorta.—The large artery which goes from the left ventricle.
Arachnoid (a spider's web).—A thin membrane covering the brain.
Areolar.—Containing little spaces, and applied to the connecting tissues of the body.
Arteries.—Tubes conveying blood from the heart.
Auricle.—The name given to the two upper chambers of the heart.
Back-bone.—Twenty-four vertebræ piled one upon another, which form a tube in which is placed the spinal cord.
Bifurcate.—Divided into two branches.
Bile.—A greenish fluid secreted by the liver. It acts on the heat-giving parts of food.
Blastema.—Matter exuded from the blood through the vessels or capillaries, and capable of organization.
Blood.—The fluid formed from our food; it consists of blood plasma or liquor sanguinis, and red corpuscles or globules.
Butyric.—Applied to an acid formed in butter.
Cæcum.—The closed end of the large intestines.
Cancellated (close-barred).—Resembling lattice work.
Capillaries.—The very minute bloodvessels found in every part of the body.
Cardiac Orifice.—The opening by which the œsophagus communicates with the stomach.
Carotid Arteries.—Those which carry blood to the head.
Cerebellum.—The lower, back part of the brain, which directs the motor nerves.
Cerebrum.—The upper part of the brain.
Cervical.—Belonging to the neck.
Cervical Vertebræ.—Those forming the neck.
Chylification.—The turning of the food into chyle.
Chyme.—Food which has been acted upon by the gastric juice.
Cilia (eyelashes).—Minute bodies projecting from various parts of the body, and having a waving motion.
Coagulation.—Setting.
Coccyx.—Four little bones placed end to end continuous with the sacrum.
Colon.—The second part of the large intestines.
Corpuscles.—The little round bodies which give colour to the blood, and which convey oxygen to all parts of the body.
Cranium.—The skull.

Curtain of the Soft Palate.—That which hangs down in front of the pharynx, separating that cavity from the mouth.
Cushion of Cartilage.—That between each of the vertebræ, and by which they are fastened together.
Cutaneous.—Belonging to the skin.
Deglutition.—Swallowing.
Dentine.—The substance of which the teeth are chiefly made.
Diastole.—The elevation or opening of the heart after contraction.
Digestion.—The reduction of the nutritious parts of food to a soluble condition, and the separation of these parts from the innutritious.
Dorsal Vertebræ.—Those forming the back, and to which the ribs are fastened (12 in number).
Duodenum.—The first twelve inches of the small intestines.
Dura Mater.—The outer covering of the brain.

EAR.—Concha and the ear-tube—the outer ear. Cavity of the Tympanum—the middle ear. Vestibule, Cochlea, and Semicircular Canals—the inner ear. Fig. 82.
Tympanum.—The membrane stretched across the tube leading from the outer ear to the middle ear.
Cerumen.—The wax secreted in the tube of the ear.
Incus, *Malleus*, *Os Orbiculare*, *Stapes.*—The four bones in the cavity of the tympanum; they are attached to the tympanum and the inner ear.
Fenestra Ovalis.—The opening or window in the inner ear opposite the tympanum, closed by a membrane and joined to the tympanum by the four bones of the middle ear.
Stapes.—The bone attached to the fenestra ovalis.
Labyrinth.—The inner ear, which is filled with a fluid like water.
Vestibule.—That part of the inner ear between the cochlea and the semicircular canals.
Cochlea.—That part of the inner ear which resembles a snail shell, and which is supposed to enable us to determine the pitch of sounds.
The Inner Ear is lined with a membrane upon which the auditory nerve is spread out to receive impressions and convey them to the brain.

Endosmose.—The process by which one fluid separated from another by a membrane mixes with it in a direction inwards from without.

Epiglottis.—The valve which covers over the glottis during swallowing.

Epiploon.—The caul, a portion of the peritoneum or lining membrane of the abdomen, which covers the front, and floats as it were on the intestines.

Epithelium.—A covering membrane formed of the same structure as epidermis, but finer and thinner.

Eustachian Tubes.—Those which conduct air from the pharynx to the middle ears.

Exosmose.—The passage of one fluid to another through a membrane from within outwards.

Expiration.—Breathing out.

EYE: Outside Coats.—Sclerotic—Tough fibrous membrane. Cornea—Convex plate of transparent horny substance. Choroid—Membrane covered with black paint. Retina—The net-like expansion of the optic nerve. Figs. 83, 84.

Inside Parts.—Aqueous humour—Watery fluid between the cornea and iris. Iris—The curtain that regulates the quantity of light. Crystalline Lens—Convex body behind the pupils. Vitreous humour—Glassy-looking substance fitting the back part of the eye. Pupil—Opening in the iris.

Six Muscles that move the Eye.—Superior rectus to draw it upwards; inferior rectus to draw it down; external rectus to draw it outwards; internal rectus to draw it inwards; superior oblique to draw it obliquely downwards; inferior oblique to draw it obliquely upwards.

Conjunctiva.—A thin transparent membrane that covers the cornea and front of the sclerotic coat, and lines the eyelids.

Yellow Spot.—That part of the retina exactly opposite the pupil; it is the most sensitive part of the retina.

Blind Spot.—That part of the retina that covers the entrance of the optic nerve.

Farinaceous.—Starchy.

Fasciculus.—A small bundle of muscular fibres.

Fat, Sugar, Starch.—The heat-giving parts of food.

Fibrin.—That substance in the blood which causes it to coagulate or thicken.

Follicle.—A little bag.

Food.—Flesh-forming substances, heat-giving substances, and mineral matter.
Function.—The office or work of an organ.
Ganglion.—A small mass of nervous matter resembling a knot.
Gastric.—Belonging to the stomach.
Gastric Glands.—Those glands in the mucous membrane which secrete gastric juice.
Gastric Juice.—A fluid secreted by the gastric glands. It contains muriatic acid and pepsin.
Glottis.—The opening into the larynx.
Hæmatin.—The substance contained by the red corpuscles.
Heart.—The large, hollow, cone-shaped muscular organ which sends blood to all parts of the body.
Heat of the Body.—98° Fahrenheit.
Heat of the Stomach.—100° Fahrenheit.
Ileum.—The lower portion of the small intestines.
Inosculate.—To open into as by little mouths.
Insalivation.—The pouring of the saliva into the mouth, and its being mixed with the food.
Inspiration.—Breathing in.
Intercostal.—Between the ribs.
Jejunum.—The second portion of the small intestines.
Lacteals.—The little tubes through which the chyle passes to the thoracic duct.
Larynx.—The top of the windpipe.
Ligaments.—Bands which wrap around the joints.
Lumbar Vertebræ.—Those at the back of the abdomen (5 in number).
Lymphatics.—The absorbent vessels, which collect unused particles from all parts of the body, and bring them back again to the thoracic duct.
Mastication.—The breaking up of the food by the teeth.
Maxillary.—Belonging to the jaws.
Medulla Oblongata.—That part of the spinal cord within the cranium.
Medullary.—The pith-like substances of the interior.
Mesenteric Glands.—The knots of lacteals in the mesentery.
Mesentery or Peritoneum.—The serous membrane which as a curtain holds up the intestines and lines the abdomen.
Mitral Valve.—The valve between the left auricle and left ventricle.
Mucous Membrane.—The lining of the mouth, œsophagus, stomach, intestines, &c.

Nerves.—Motion; Sensation; Special sense, such as gustatory, olfactory, sympathetic.
Neurilèmma.—The sheath of a nerve.

NOSE.—An irregular cavity situated above the mouth, lined with mucous membrane. The tears are brought into it by a tube from a lachrymal sac. Fig. 81.
Arched Palate of Bone.—That which separates the cavity of the mouth from the nose.
Sinuses.—Cavities in the bones of the skull which open into the nose.
Olfactory Nerve.—The nerve that is spread out upon the mucous membrane of the nose to receive impressions, which it conveys to the brain.

Œsophagus.—The food-pipe or gullet, which passes down behind the windpipe or trachea.
Oleaginous.—Oily or fatty.
Organ.—Any part of a living body which has a particular function or work to perform.
Organs of Purification.—Skin, lungs, kidneys.
Os Hyoides.—The tongue bone.
Osseous.—Bony.
Pale or Colourless Corpuscles.—Red ones in the process of making.
Pancreas.—A fleshy organ behind the stomach which secretes pancreatic juice.
Papillæ.—Little eminences which cover the tongue and ends of the fingers.
Parietal.—The large flat bone on the side of the head.
Parotid.—Near the ear.
Pericardium.—The serous membrane enclosing the heart.
Peristaltic Action.—The movement of the stomach and intestines during digestion, by which the food is turned about in the stomach and intestines.
Perspiration.—Sweat; that which comes through the skin.
Pharynx.—The back part of the mouth, or top of the throat.
Physiology.—A knowledge of the functions which the various parts of the body perform during health.
Pia Mater.—The inner covering of the brain.
Plasma.—Liquor sanguinis, or the liquor of the blood.
Pleura.—The serous membrane that lines the thorax and forms bags in which the lungs are placed.

Pulmonary.—Belonging to the lungs.
Pylorus.—The smaller end of the stomach through which the chyme passes into the small intestines; this opening is guarded by a valve.
Rectum.—The last part of the large intestines.
Respiration.—Breathing.
Ribs.—We have seven true and five false ribs on each side.
Saccharine.—Sugary.
Sacrum.—The wedge-shaped bone on which the back-bone rests.
Salivary glands.—Parotid, near the ear; sub-maxillary, near the angles of the lower jaw; sub-lingual, under the tongue.
Semilunar Valves.—Those between the right ventricle and the pulmonary artery, and between the left ventricle and aorta.
Sensorium.—That part of the brain which receives the nerves of sensation.
Serous Membranes.—Membranes which line the closed cavities of the body, such as the arachnoid.
Serum.—The watery part of the blood.
Spinal Cord.—Nervous matter found in the back-bone.
Structure.—Manner of building.
Subclavian.—Under the clavicle or collar-bone.
Subclavian Arteries.—Those which carry blood to the arms.
Tenacity.—The power of holding together.
Tendons.—Strong fibrous strings by which muscles are fastened to the bones.
The forms of Tissue are—Cellular or areolar, muscular, nervous.
Thoracic Duct.—The tube into which the lacteals and lymphatics empty themselves.
Tissue.—A particular arrangement of the fibres in an organ.
Trachea.—The windpipe.
Tricuspid Valve.—The valve between the right auricle and right ventricle.
Uvula.—The small fleshy part which hangs down at the back of the soft palate.
Vascular.—Containing a large number of bloodvessels.
Veins.—Tubes or vessels which convey blood to the heart.
Ventricle.—The name given to the two lower chambers of the heart.
Villi.—The roots of the lacteals, which suck up or absorb the chyle.
Viscera.—The organs contained in the great cavities of the body.
Viscid.—Sticky.

APPENDIX.

Questions given at former Examinations of Science Schools and Classes; only Eight have to be answered, and Three Hours are allowed for the Examination.

ANIMAL PHYSIOLOGY.

1. What are the chief constituents of the blood, and in what proportions do they occur?
2. How many salivary glands are there? Where are they placed, and what functions do they perform?
3. Describe the mechanism of respiration, and the changes which take place in respired air.
4. What is meant by the "contraction" of a muscle, and by what arrangements is muscular contraction made available to produce locomotion in man?
5. What are cilia? Where do they occur in man?
6. What are the general structure and arrangement of the parts of the brain?
7. Why are certain nerves termed cerebral, and what organs and parts of the body are supplied by those nerves?
8. What is the ultimate structure of nervous substance as revealed by the microscope?
9. Where is the nervous apparatus of the sense of touch lodged, and how may the degree of the acuteness of that sense in different parts of the body be estimated?
10. Where is the organ of the sense of smell situated? Explain what takes place in the respiratory organs when one snuffs up an odour; and what is the use of that operation?
11. What is the ordinary temperature of the body, and how is that temperature kept up and regulated?
12. Describe the structure of any joint between bones freely moveable on one another.
13. How is the eye moved, and how are the eyelids raised and depressed?
14. What is the structure of bone?

15. Where does cartilage occur in the human body, and what is its structure?
16. What is the structure of the tissues called "epithelium" and "epidermis," and where do they occur?
17. What are cilia? Where are they found in the human body?
18. How many kinds of "corpuscles" are there in the blood, and what are their distinctive characters?
19. Describe the circulation of the blood.
20. Where is the liver placed; what is its secretion; and how is that secretion poured into the intestine?
21. What is the structure of the tissue called "striped muscle," and what are its properties?
22. Enumerate the structures which enter into the composition of the eye.
23. Enumerate and explain the action of the muscles of the eye and eyelids.
24. What is meant by the "adjustment" of the eye, and how is it effected?
25. Give an account of the structure of the ear.
26. What is the "pulse"? why is no pulse observable in the veins?
27. What glands secrete saliva or a similar fluid? what are the functions of the saliva?
28. What is "lymph"? Give a general account of the lymphatic system.
29. By what means are the products of digestion absorbed into, and the products of waste eliminated from, the blood?
30. By what conditions is the temperature of the human body determined?
31. Describe the mechanism of breathing, and the changes undergone by the air inspired and expired.
32. What are the ribs? How many does a man possess, and what cavity do they help to enclose?
33. Give an account of the general form of the brain and the spinal cord, and state how they are protected.
34. What are the different kinds of food? Why is the grain of wheat good for human food and the straw not?
35. Where is the heart placed? How many chambers does it contain, and what is the course of the blood through them?
36. How does air which has been breathed differ from pure air, and what is the cause of the difference?
37. What are muscles? State where muscles are found.

38. Why are teeth hard? How many sorts of teeth are there?
39. What is the saliva, and where is it formed?
40. What is a joint? In what way does the hip joint differ from the elbow joint?
41. What is the retina, and what is its function?
42. What is the general structure of bone, and by what mineral substances are bones made hard?
43. What is the difference between tendon, ligament, and cartilage?
44. How do the capillaries differ from the small arteries and veins in structure and in function?
45. How many valves are to be found in the heart? What are their names and what their uses? In what other localities in the vascular system are valves found?
46. Give an account of the structure and uses of the diaphragm.
47. What are the structure and functions of the kidneys?
48. What is the amount and what the general nature of the substances which an adult healthy man, properly fed, takes into and gives out of his body *per diem?*
49. What are cilia? Where do they occur in the human body?
50. What are the different kinds of levers? Give an example of each in the human body.
51. Give an account of the manner in which the voice is produced and regulated.
52. How are the eyelids and the eyeball moved, and how are the tears secreted and carried away?
53. Briefly describe the structure of the eyeball, and give an account of the uses of its different parts.
54. What are the most obviously distinguishable parts of the brain? Enumerate the pairs of nerves to which the brain gives rise.
55. What is the structure of the spinal cord? What are the roots of the spinal nerves, and how have their functions been determined?

INDEX.

Abdomen, cavity of, 65; respiration, 150.
Absorption, definition of, 8, 85.
Acids, nature of, 11.
Acini of salivary glands, 169.
Action of the heart, 129.
Adam's apple, 216, 217.
Adipose tissue, 258.
Age, bones in old, 191; death from, 280.
Air, composition of, 142; quantity respired, 154; why it passes into the lungs, 154.
Air-cells, 153.
Albumen, 15.
Alcohol not a supporter of animal heat, 111; increases the waste of the system, 112.
Alimentary canal, 62; gases of, 83.
Alkalies, nature of, 13.
Alveoli, 48.
Ammonia in blood, 124; in respired air, 142.
Amœba, 4.
Anastomosis of veins and arteries, 135.
Anatomy, definition of, 6.
Animals and plants contrasted, 6.
Animate bodies, 1.
Aorta, 44, 127, 131, 133, 134.
Aqueous humour, 248, 251.
Arachnoid membrane, 232.
Areolar tissue, 257.
Arterial blood, 117; temperature of, 156.
Arterial system, diagram of, 134.
Arteries, 133; coats, 134; movement of blood in, 136; wounded, 136.
Articulations or joints, 212.
Asphyxia, 155; death from, 155.
Atavism, 277.
Atlas vertebra, 199.
Auricles, 127, 129.
Axis vertebra, 199.
Azotized proximate principles, 15.
Baldness, 186.
Barley, 105.
Basement membrane glands, 158; of skin, 180; description of, 268.
Beaumont, Dr., what he saw in the stomach, 56.
Beer, 112.
Bicuspid teeth, 32.
Bile, 80; properties of, 167; composition and functions, 167; a poison, 168.
Biliary cells, 162.
Bladder, gall, 166; urinary, 177.
Blastema, 269, 272.
Blood, 117; quantity of, 118; structural character and composition, 118; red corpuscles, 120; white corpuscles, 120; liquor sanguinis, 121; vital properties, 121; coagulation of, 122; serum of, 123; serosity, 123; gases in, 124.

Bone, 190; composition of, 259; structure of, 260.
Bones, repair of broken, 157; description of, 191, 192.
Brain, parts of, 225.
Bread, what becomes of, when eaten, 83.
Breath. See Respiration; respired air, 8, 140, 154.
Bronchi, 152.
Bronchial tubes, 152.
Bronchitis, 155.
Butter, what becomes of, when eaten, 84; as heat-forming food, 109.
Cæcum, 73.
Canal, alimentary, 83.
Canine teeth, 32.
Capillaries, gastric, 51, 52; description of, 137; of skin, 182.
Carbon, 18; consumed per day by man, 24.
Carbonic acid, 143; source of, in body, 143; theory of production, 144.
Carpenter's plane, 18.
Cartilage, 257.
Casein, 16.
Cataract, 251.
Cell, 271; nature and development of, 271.
Cerebellum, 229.
Cerebrum, 227; function of, 229.
Change, annual, of bodily substance, 20; in expired air, 142; in blood, 142; of animal existence, 276.
Cheese, 113.
Chemistry, a knowledge of, indispensable in physiology, 10.
Chest. See Thorax, 146.
Chondrin, 17.
Choroid, coat of the eye, 248, 249.
Chyle, 80; corpuscles, 82; movements of, 92.
Chyme, 53.
Chymification, 42.
Cilia, 152, 270.
Ciliary muscle, 248, 254; ligament, 249.
Ciliated epithelium in trachea, 152.
Circulation, definition of, 8; purpose of, 126; organs of, 126; diagram of, 125, 127; division into greater, lesser, and portal, 131.
Clavicle, 204.
Cleanliness, importance of, 186.
Clot or crassamentum, 123.
Clothing, effect of, on respiration, 154.
Coagulation of blood, 122; causes of, 123.
Coats of stomach, 42; of intestines, 63.
Cochlea, 244, 245.
Cocoa, 111.
Coffee, 110.
Colon, 74.
Colour-blindness, 251.
Coma, death from, 279.
Combe's (Dr. A.) "Physiology of Digestion," 113.
Concha, 244.
Condiments, 112.
Constipation, 77.
Contraction, muscular, 214.
Convolutions of brain, 230.
Cooking, 114.
Cord, spinal, 234—237; vocal, 220.
Corium, 181.
Cornea, 247.

Cornua of spinal cord, 233.
Coronary arteries, 130.
Corpuscles, blood and lymph, 118; white, 120.
Costæ, 201.
Course of blood, 132; tabular view of, 133; of motor impulses, 237; of sensory impressions, 238.
Cranial nerves, 231.
Cranium. See Skull, 194.
Crassamentum or clot, 123.
Cricoid cartilage, 217.
Cruor, 122.
Crystalline lens, 251.
Cuticle, 180.
Cutis, 181.
Death, what caused by, 1; description of, 277.
Decay, combustive and disintegrative, 92; of red corpuscles, 120.
Decomposition, vital, 24.
Decussation, 233.
Deglutition, definition of organs of, 37; stages in, 37.
Dentine, 261.
Dermis, 181.
Development, 27.
Diaphragm, 44, 146, 147.
Diarthrosis, 212.
Diastole, 132.
Difference between plants and animals, 6, 7.
Diffusion, liquid, 61.
Digestibility of different kinds of food, 113.
Digestion, definition of, 8; general view of, 29; subprocesses of, 29; stomach or gastric, 42; artificial, 53; intestinal, 61; summary of, 61.
Diploë, 194.
Disease, what caused by, 2.
Division of natural bodies, 1; of organized bodies, 3; of physiological labour, 6.
Drowning, 156.
Drum of the ear. See Tympanum, 245.
Duct, salivary, 36; thoracic, 89; biliary, 161, 165; pancreatic, 170; sudoriparous, 186.
Duodenum, 62, 68.
Dyspepsia, 83.
Ears, 244.
Economical admixture of food, 113.
Education, 222, 277.
Eggs, digestibility, 113.
Elements, proximate, 17; chemical, 3.
Enamel, 33.
Endosmose, 60.
Epidermis. See Cuticle, 180.
Epiglottis, 219.
Epithelium cells, 269.
Eustachian valve, 129; tube, 244.
Examination, Government Science Papers, 294—296.
Excretion, definition of, 8.
Exosmose, 61.
Expiration, 149.
Eyeball, muscles of, 254.
Eyes, 247; appendages of, 252; adjustment of, 254.
Fæces, 82.
Fat, 17; consumed in cold climates, 109.
Fibrin, 15; of blood, 123.
Flesh meat, 104.
Flour, wheaten, 105.
Food, is force, 22; quantity required dependent on waste, 95; nitrogenous, consumed,

an exponent of work, 96; quantity per day, 98; classification of, 102; definition of, 102; plastic, 103; heat-forming, 108; economical admixture, 113.
Force, physical, in living beings, 5; selective, 140; nerve, 266.
Forces, which propel the lymph and chyle, 92; of the circulation, 139.
Function, definition of, 1; organic or vegetative, 8; animal, 9; of relation and organic or vegetative, 27; of plants in relation to animal life, 92.
Gall-bladder, 166.
Ganglion, 240.
Gases in alimentary canal, 83; in blood, 124.
Gastric juice contains chlorine, 53; tubuli or follicles, 49; capillaries, 50.
Gelatin, 16.
Germ, 271; cell, 272.
Glands, salivary, 36, 168; duodenal or Brunner's, 72; lymphatic, 87; mesenteric, 89; structure of, 158; ductless, 171.
Glisson's capsule, 163.
Globulin, 16.
Gluten, 108.
Glycogenic function of liver, 168.
Gout, chalkstones, 179.
Gravel, 179.
Gullet. See Œsophagus, 40.
Gum, 17.
Hæmatin or hæmatosin, 16.
Hair, 186.
Haversian canal, 260.
Head, bones of, 199.
Hearing, organs of, 244.
Heart, 128; valves of, 129; nourishment of, 130; sounds of, 132.
Heat, animal, 156; regulated by skin, 188; generated in man, 156.
Heat-forming food, 108; consumed by Esquimaux, 109.
Hepatic cells and vein, 162, 164; artery, 164; ducts, 165.
Histology, definition of, 6.
Humerus, 205.
Humours, aqueous, 251; crystalline, 251; vitreous, 252.
Hunger, 114; cause of, 115.
Huxley, Professor, the importance of chemistry in physiology, 10.
Ileum, 69.
Incisor teeth, 31.
Infancy, bones of, 191; reflex action, 240.
Insalivation, 36.
Inspiration, 147.
Instinctive actions, 241.
Intestinal digestion, 61; juice, 80.
Intestines, large and small, 63; serous, muscular, and mucous coats, 78; bloodvessels, 79; nerves, 80; lacteals, 80.
Intralobular veins, 162, 164; spaces, 166.
Involuntary muscles, 213.
Iris, 240.
Jaundice, 167.
Jejunum, 68.
Joints, 212.
Juice, gastric, 51, 52; intestinal, 80; pancreatic, 80.
Kidneys, 173; structure of,

174; circulation of, 176; function, 178; Malpighian bodies, 176.
Labour, physiological, 6.
Lachrymal apparatus, 253.
Lacteals, 71, 89.
Lactic acid in gastric juice, 53; in perspiration, 185.
Larynx, 151; description of, 151; functions of, 221.
Legumin, 108.
Lentils, 107.
Levers in the human body, 211.
Life, definition of, 3.
Light, nature of, 252.
Liquor sanguinis, 121, 123.
Liver, 190; lobules, 164, 165; functions, 168; structure, 160.
Lobes of lungs, 151.
Lobules of lung, 150; liver, 166.
Locomotion, 9, 25, 27, 213.
Long sight. See Presbyopia, 255.
Lungs, 140; description of, 141; structure of, 150.
Lung-sacs, 153.
Lymph, 88; movements of, 92; globule, 118; coagulable, 157.
Lymphatics, course and distribution of, 86; structure, 86; their glands, 87; functions of, 87.
Machine, the living body considered as, 22.
Malpighian corpuscles, 172; pyramids, 176; bodies, 176.
Man, functional view of, 24; structural view of, 25; table of organs and functions of, 26.
Marrow, 193.
Mastication, definition and movements of, 30.
Mechanics, animal, 189.
Medulla oblongata, 233.
Membranes, mucous, 268—270; secreting plan of, 159; serous, 267.
Mental operations, 223.
Mesenteric glands, 89.
Mesentery, 67.
Milk, human, 104; cows', 104; teeth, 34.
Mineral food, 103.
Mitral valve, 127, 129.
Molar teeth, 32.
Molecular death, 277.
Motion, 212; nerves of, 238.
Motor nerves, 224, 231, 310.
Moulting feathers, 278.
Mouth, 30.
Mucus, 270.
Murder, coagulation after, 123.
Muscles, 212, 213; of eyeball, 254.
Muscular tissue, 261—264.
Mutton chop, what becomes of, when eaten, 84.
Myolemma. See Sarcolemma, 263.
Myopia, or short sight, 254.
Nails, 187.
Necræmia, 280.
Nerve, auditory, 246; tissue, 264.
Nerves of stomach, 59; heart, 130; lungs, 154; cranial, 232, 233; spinal, 238.
Nervous system, 222.
Neurilemma, 265.
Nitrogen, 100; excreted and consumed daily, 100.
Nitrogenous food, 96, 103.
Non-azotized proximate principles, 17.

Nose, 242.
Nutrition, definition of, 8; process of, 156; condition of, 157.
Nutritiousness and digestibility, 113.
Oatmeal, 106.
Œsophagus, 40.
Old age, bones in, 191; death from, 180.
Olfactory lobes, 225, 243.
Optic nerves, 228, 246, 247.
Orbits, 196.
Organ, definition of, 1.
Organization, definition of, 1; low, 4; high, 5.
Organized bodies, properties of, 3.
Organogens, 14.
Osmosis, 59.
Osseous tissue, 259.
Outline of intestinal digestion, 62; of large and small intestines, 63.
Oxygen gas in the blood, 124.
Pacinian corpuscle, 184.
Palate, soft, 38.
Pancreas, 169; structure of, 170; functions, 171.
Pancreatic duct, 170; juice, 170.
Papillæ of skin, 182.
Pathology, definition of, 6.
Peas, 167.
Pectoral respiration, 150.
Pelvis, 203.
Peptone, 53.
Pericardium, 127.
Perichondrium of trachea, 152.
Periosteum of broken bone, 192; description of, 193.
Peristalsis of stomach, 46; of intestines, 75; cause of, 78.
Peritoneum, 66.
Perspiration, sensible and insensible, 184.
Perspiratory function of skin, 184.
Pharynx, structure and functions of, 40.
Physiology, definition of, 6.
Pia mater, 230.
Pigment cells, 181, 249, 273.
Plants in relation to animal life, 42.
Playfair, Dr., researches on food, 96.
Pleura, 150.
Pores of skin, 181.
Portal circulation, 131; canal, 163; vein, 163.
Potatoes, 106.
Prehension, 29.
Principles, proximate, 2; ultimate, 2; azotized, 15.
Properties of organized bodies, 3.
Protein, 15.
Pulmonary circulation, 131; veins and arteries, 141.
Pulse, 138.
Pupil, 249.
Purgatives, 77.
Pylorus, 62, 67.
Pyramids, Malpighian, 176.
Receptaculum chyli, 90.
Rectum, 74.
Reflex action, description of, 240, 241.
Refraction, 252.
Renal arteries and veins, 177.
Repair of injuries, 157; broken bone, 157.
Reproduction, definition of, 9, 271—277.
Respiration, definition of, 8; organs of, 140; experiments in, 140, 141; movements of,

147; muscles of, 149; nerves of, 154; artificial, 155; by skin, 184.
Respiratory food, 115.
Respired air, 142.
Rete mucosum, 181.
Retina, 249.
Rheumatism, 185.
Ribs or costæ, 201.
Rice, 107.
Roots of motor and sensory nerves, 235.
Rye, 106.
Salines, required daily, 101.
Saliva, 38; composition, 37.
Salivary glands, 36; structure of, 169.
Sarcolemma, 263.
Scapula, 204.
Sclerotic coat, 247.
Sebaceous glands, 186.
Secretion, definition of, 8; organs of, 158.
Semilunar valves of veins, description of, 138.
Sensation, definition of, 9; seat of senses, the, 241—255.
Sensorium, 229, 231.
Sensory nerves, 224; impression, course of, 238.
Septum auriculorum and ventriculorum, 127.
Serosity of blood, 123.
Serous membranes, 267; fluid, 267.
Serum, 123.
Short sight. See Myopia, 254.
Sight, 246.
Sigmoid flexure, 62.
Singing, 222.
Skeleton, 189.
Skin, 179; nerves and relative sensibility of, 182; a respiratory organ, 184.
Skull, 195.
Smell, sense of, 242.
Smith, Dr. E., researches on food, 100.
Somatic death, 279.
Sounds of heart, 132.
Sound waves, 245.
Speech, 214.
Sphincter muscle, 62, 213.
Spinal cord, 234.
Spirits, 112.
Spleen, 171; Malpighian corpuscles of, 172; functions of, 172.
Spontaneous motion, 9.
Spot of Sömmering, 250.
Stammering, 222.
Starch, 17.
States of organization, 3.
Sternum, 202.
Stethoscope, 132.
Stimulants, 109; tea, 109; coffee, 109; alcoholic, 111.
Stomach, structure of, 42; situation, 45; serous coat, 45; muscular coat, 45; vermicular action, 46; mucous coat, 48; bloodvessels, 57; nerves and lymphatics, 59.
Strangulation, 155.
Suction, 41.
Sudoriparous glands, 186.
Suffocation, 155.
Sugar, 17.
Summary of food, hunger, and thirst, 115; of digestion, 91.
Sutures, 195.
Sweat glands. See Sudoriparous glands, 180, 186.
Sweetbread. See Pancreas, 161, 170.
Sylvester's, Dr., method of restoring respiration, 156.

Sympathetic nervous system, 239.
Syncope, death from, 279.
Synovial membranes, 268; fluid, 268.
Synthetic power of plants, 42.
Syntonin, 16.
Systole, 132.
Taste, sense of, 241.
Tea, 110.
Tear gland. See Lachrymal gland, 253.
Teeth, 31; structure of, 32; enamel of, 33; milk, 34; development of, 34; decay of, 34.
Temperature of arterial blood, 156.
Tendons, 214.
Thirst, 115.
Thoracic duct, 90.
Thorax, 146; structure and movements, 145; bones of, 202.
Thought, dependent on the brain, 9.
Thymus gland, 173.
Thyroid gland, 173; cartilage, 217.
Tissue, definition, 2; repair and renovation of, 126.
Tissues, description of, 255.
Tobacco, 225.
Tongue, 38, 241.
Touch, sense of, 241.
Trachea, 151.
Tricuspid valves, 127, 129.
Trunk, bones of, 198.
Turkish bath, 188.
Tympanum, 245.
Urea, 178, 179; a test of work, 1.
Ureters, 177.
Uric acid, 179.
Uriniferous tubuli, 175, 176.
Vacuum, 41, 147, 154.
Valves, ileo-cæcal, 74; of lymphatics, 87; of heart, 127, 129; of veins, 139.
Valvulæ conniventes, 43.
Varolii, pons, 226.
Vegetables, 45.
Vegetative functions, 8.
Veins, pulmonary, 138; description of, 129; valves of, 139; interlobular and intralobular, 162, 163; sublobular, 164.
Vena cava, 44, 127.
Venous blood, 117.
Ventilation, 154.
Ventricles, 127—129.
Vermiform appendix, 74.
Vertebræ, 200.
Vertebral column, 197.
Vesicle, nerve, 266.
Vestibule of ear, 245.
Villi, intestinal, 69.
Villus, structure of, 70; capillaries of, 71.
Vision, single, 255; erect, 255; binocular, 255.
Vitreous humour, 252.
Voice, 214.
Voluntary muscles, 213.
Waste, 18; proved by starvation, 19; rate of, 19; daily, 20; annual, 20; causes of, 21; proportional to exertion, 21; how determined, 22.
Water, 101.
White corpuscles, 120; fibrous tissue, 256.
Windpipe. See Trachea, 151.
Wines, 112.
Wounded artery, 136.
Yellow fibrous tissue, 256.